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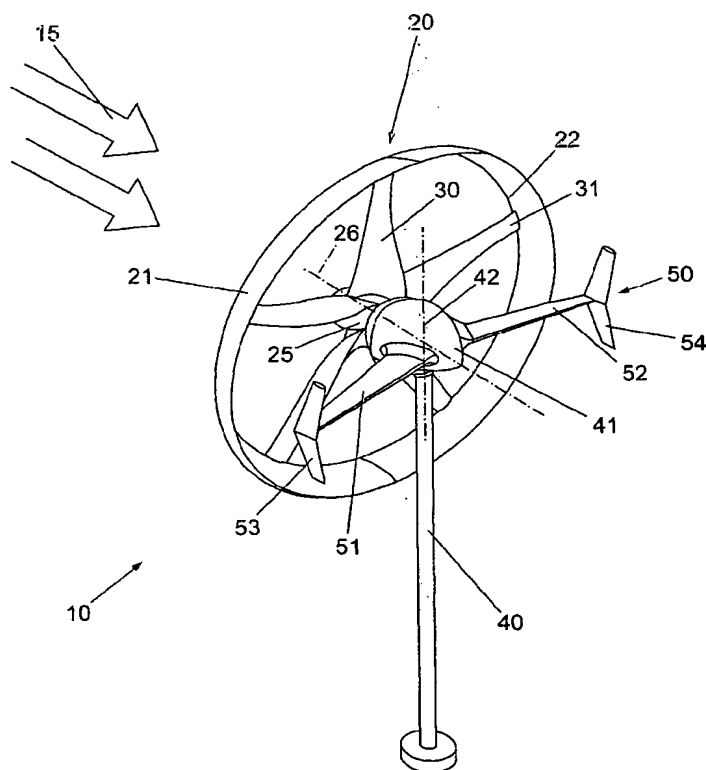
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(54) Title: **WIND TURBINE**



(57) Abstract: There is described herein a rotor for a wind turbine comprising a plurality of radial blades and a ring-shaped aerofoil diffuser connecting the outer tips of the blades. Further there is described a wind turbine comprising said rotor and further comprising a nacelle and a mounting means adapted to allow rotation of the turbine and rotor about a directional axis perpendicular to the rotational axis, thus allowing the turbine to be oriented in the optimum direction depending on wind conditions. A furling means is disclosed to effect a change in orientation depending on wind speeds. A wind turbine system is also disclosed comprising: a wind turbine driven generator and means for providing a power output, the power output connected to a heating system, a grid-tie inverter or stand alone inverter adapted to supply power to local or grid power infrastructure, or an energy storage system. A method of controlling the level of power taken from a wind turbine; and a wind turbine comprising means for reducing the operating vibrations caused by harmonic resonance within the turbine, tower and mounting structure are also described.

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14 SEP 20051 Wind turbine

2

3 The invention relates to wind turbines, and more
4 particularly to a wind turbine for mounting on a
5 roof and for use with a heating system (either
6 domestic or commercial), energy storage system,
7 electrical storage system or with a local or
8 national electricity grid.

9

10 The UK government, under the Kyoto agreement, made a
11 commitment to decrease CO₂ emissions by 10% by 2010
12 and the Scottish Executive have set even more
13 stringent environmental targets. Accordingly, there
14 has recently been emphasis on renewable sources of
15 energy. Analysis of energy demands shows that 47%
16 of the UK's annual energy demand is from buildings,
17 which contributes 40% of the UK's CO₂ emissions.

18 The technology of the present invention will provide
19 substantial economic benefits to over 33% of
20 buildings and could reduce the UK's CO₂ emissions by
21 as much as 13%.

22

CONFIRMATION COPY

1 Existing turbines of a size suitable for mounting on
2 a roof to provide power are designed for smooth
3 airflow only and will oscillate violently with the
4 compressed and turbulent airflow found over, and
5 around, buildings, creating noise and inefficient
6 generation.

7

8 It is an object of the present invention to overcome
9 one or more of the aforementioned problems.

10

11 According to a first aspect of the invention there
12 is provided a rotor for a wind turbine comprising a
13 plurality of radial blades and a ring-shaped
14 aerofoil diffuser connecting the outer tips of the
15 blades.

16

17 Preferably the aerofoil diffuser extends downstream
18 from the outer tips of the blades. The outer tips
19 of the blades may be connected to the diffuser at or
20 near to the leading edge of the diffuser.

21

22 Preferably the aerofoil diffuser tapers outwards
23 from the outer tips of the blades to form a
24 substantially frusto-conical diffuser, the
25 rotational axis of the frusto-conical diffuser is
26 substantially aligned to the rotational axis of the
27 blades.

28

29 Alternatively, at least a portion of the aerofoil
30 diffuser extends upstream from the outer tips of the
31 blades, the aerofoil diffuser tapers radially

1 outwards as it extends from the upstream end to the
2 downstream end.

3
4 Preferably the aerofoil diffuser is shaped such that
5 it inhibits the partially axial and partially radial
6 airflow from the blades, said airflow becoming
7 circumferential when it contacts the aerofoil
8 diffuser. Further preferably the shape of the
9 aerofoil diffuser is such that there is a resultant
10 improvement in the aerodynamic and acoustic
11 characteristics of the blade and diffuser assembly
12 when in rotation.

13
14 Preferably the aerofoil diffuser is adapted to
15 inhibit partly axial and partly radial airflow from
16 the outer tips of the blades and divert said airflow
17 to circumferential airflow during normal operation.

18
19 Preferably the blades are inclined at an angle
20 relative to a transverse rotor plane perpendicular
21 to the rotational axis of the rotor. The angle of
22 inclination may vary along the length of the blade.

23
24 Preferably the angle of inclination of each blade is
25 greater at an intermediate portion of the blade than
26 at the outer tip of the blade. Preferably the blade
27 is substantially parallel to the transverse rotor
28 plane at the outer tip of the blade.

29
30 According to a second aspect of the invention there
31 is provided a wind turbine comprising a rotor
32 according to the first aspect. Preferably the wind

1 turbine further comprises a nacelle and a mounting
2 means adapted to allow rotation of the turbine and
3 rotor about a directional axis perpendicular to the
4 rotational axis. This allows the turbine to be
5 oriented in the optimum direction depending on wind
6 conditions.

7
8 Preferably the wind turbine further comprises a
9 furling means adapted to rotate the rotor about the
10 directional axis so that the rotational axis is not
11 parallel to the direction of airflow when the
12 airflow speed is greater than a predetermined
13 airflow speed.

14
15 Preferably the furling means comprises a non-linear
16 furling means adapted to provide no furling over a
17 first lower range of airflow speed and a varying
18 degree of furling over a second higher range of
19 airflow speed. Preferably the furling means
20 comprises at least two tail fins extending
21 downstream of the diffuser. Preferably the furling
22 means comprises two tail fins provided diametrically
23 opposite each other, but more tail fins may be
24 provided if required, providing the positions of the
25 tail fins are balanced.

26
27 Preferably one of the tail fins is a moveable tail
28 fin hingedly mounted for rotation about a tangential
29 hinge line. The moveable tail fin may be mounted on
30 a mounting boom and the hinge line may be provided:
31 at the connection point of the mounting boom and the
32 nacelle, so that the mounting boom also rotates; at

1 the connection between the mounting boom and the
2 moveable tail fin so that only the moveable tail fin
3 rotates; or at any point along the length of the
4 mounting boom.

5
6 Additionally or alternatively, the tail fin may
7 rotate about a horizontal axis under high winds
8 resulting in a fin which folds about a horizontal
9 axis.

10
11 Preferably the moveable tail fin is rotationally
12 biased by biasing means to an at-rest position in
13 which the leading edge of the moveable tail fin is
14 closer to the axis of rotation of the rotor than the
15 trailing edge of the moveable tail fin, such that
16 the moveable tail fin is angled at an at-rest attack
17 angle to the axis of rotation of the rotor. The
18 biasing means may be non-linear. Preferably the
19 biasing means is adapted to hold the moveable tail
20 fin in the at-rest position until the airflow speed
21 reaches a predetermined speed. Preferably, as the
22 airflow speed increases beyond the predetermined
23 speed the moveable fin rotates and the attack angle
24 decreases. This results in unbalanced aerodynamic
25 loading on the wind turbine, so that the wind
26 turbine rotates about its mounting axis to a furled
27 position.

28
29 According to a third aspect of the present invention
30 there is provided a wind turbine system comprising:
31 a wind turbine driven generator and means for
32 providing a power output.

1

2 Preferably the system further comprises an
3 electronic control system.

4 Preferably the system comprises a dump element
5 comprising one or more energy dissipaters. The
6 energy dissipaters may be in the form of resistive
7 elements.

8

9 Preferably the dump element is in the form of a
10 liquid storage vessel having electrical heating
11 elements therein adapted to heat liquid in said
12 storage vessel.

13

14 Preferably the control means may be adapted to
15 supply electrical power to said one or more
16 electrical heating elements when the power from the
17 wind turbine exceeds a predetermined power. In one
18 embodiment the liquid storage vessel is a cold water
19 tank and the liquid is water. In another embodiment
20 the heating element is a radiator.

21

22 Preferably this dump element is activated by the
23 electronic control system when the power available
24 from the wind exceeds the power take-off due to a
25 loss or reduction of electrical load caused by the
26 switching off, reduction or separation of the said
27 electrical load.

28

29 Preferably said dump element is activated when the
30 rotor speed increases above a defined "dump on"
31 rotor speed caused by the imbalance of wind turbine
32 rotor torque and wind turbine generator torque. The

1 said wind turbine rotor torque is dependent on wind
2 speed and the said wind turbine generator torque is
3 dependent on the electrical load.

4
5 Further, said dump element serves to increase the
6 wind turbine generator torque above the wind turbine
7 rotor torque reducing the wind turbine rotor speed
8 until it approaches or reaches an aerodynamic stall.
9 The dump load is then released when the wind turbine
10 rotor speed falls below a defined "dump off" rotor
11 speed. The said "dump on" and "dump off" rotor
12 speeds are defined proportionally to the power take-
13 off thus reducing the generator torque.

14
15 Preferably, the wind turbine system according to the
16 present invention is provided with a control means
17 in order to control the level of power taken from
18 the wind turbine. For efficiency reasons the
19 maximum power take-off from the wind turbine is
20 approximately 60%, as given by the Betz limit. The
21 control system is adapted to increase or decrease
22 the power take-off from the wind turbine by a small
23 amount and temporarily set the power take-off at
24 this level. After a certain time period, the
25 control system will measure the rotor speed of the
26 wind turbine again and thus calculate the
27 acceleration of the rotor. Additional measurements
28 of rotor speed are then made after additional time
29 periods. These are used to calculate the first,
30 second and third order values, namely speed,
31 acceleration/deceleration and the rate of change of
32 acceleration/deceleration, to the said increase or

1 decrease in power take-off. A combination of the
2 said first, second and third order values determines
3 a change in the existing power take-off and the
4 amount of power taken from the wind turbine is again
5 adjusted. The above steps are repeated
6 continuously.

7
8 Preferably the system comprises a wind turbine
9 according to the first or second aspects of the
10 invention.

11
12 The power output may be connected to a heating
13 system further comprising a further liquid storage
14 vessel,
15 one or more electrical heating elements adapted
16 to heat liquid in said further vessel, and
17 control means adapted to control the supply of
18 electricity generated by said generator to said one
19 or more electrical heating elements.

20
21 Preferably the further liquid storage vessel is a
22 hot water tank and the liquid is water.

23
24 Additionally or alternatively, the heating system
25 comprises a plurality of electrical heating
26 elements, and the control means is adapted to supply
27 electrical power to a proportion of the electrical
28 heating elements, the proportion being dependent
29 upon the instantaneous electrical power generated by
30 the generator.

31

1 Preferably the heating element in the further liquid
2 vessel is enclosed by means of a tube. This tube is
3 open on the underside thereof in order to allow
4 water to flow from beneath the tube towards the
5 heating element. The tube will enclose and extend
6 over in essence the entire length of the heating
7 element. The water near the heating element will be
8 heated and will flow upwards due to natural
9 convection. The presence of the tube will direct
10 the heated water towards a zone near to or at the
11 top of the vessel. The presence of the tube will
12 enable the formation of different and separate
13 thermally stratified heat zones within the further
14 liquid storage vessel.

15
16 Alternatively or additionally, the power output may
17 be connected to a grid-tie inverter or stand alone
18 inverter. Preferably the inverter is adapted to
19 supply power to local or grid power infrastructure.

20
21 Alternatively or additionally, the power output may
22 be connected to an energy storage system.

23
24 According to a fourth aspect of the present
25 invention there is provided a method of controlling
26 the level of power taken from a wind turbine
27 comprising the following steps taken by a control
28 means:

- 29 (a) increasing or decreasing the power take-off
30 from the wind turbine by a small amount;
31 (b) temporarily setting the level of power take
32 -off;

- 1 (c) after a predetermined time period, taking a
2 number of measurements of the rotor speed;
3 (d) calculating the first, second and third
4 order values, namely speed,
5 acceleration/deceleration and rate of change
6 of acceleration/deceleration respectively,
7 to the said increase or decrease in power
8 take-off;
9 (e) adjusting the power taken from the wind
10 turbine in response to the calculation.

11

12 Preferably steps (b) to (e) are repeated
13 continuously.

14

15 Preferably the control means uses the following
16 logic to determine the adjustment:

- 17 (a) IF: there is a positive second order rotor
18 speed response (acceleration) and an
19 increasing rate of said acceleration
20 (positive third order response) of the rotor
21 speed; THEN: the control means causes an
22 increase in the power take-off; OR
23 (b) IF: there is a positive second order rotor
24 speed response (acceleration) and decreasing
25 rate of said acceleration (negative third
26 order response) of the rotor speed; THEN:
27 the control means causes an increase or
28 alternatively no change in the power take-
29 off; OR
30 (c) IF: there is a negative second order rotor
31 speed response (deceleration) and increasing
32 rate of said deceleration (positive third

1 order response) of the rotor speed; THEN:
2 the control means causes a reduction in the
3 power take-off; OR
4 (d) IF: there is a negative second order rotor
5 speed response (deceleration) and decreasing
6 rate of said deceleration (negative third
7 order response) of the rotor speed; THEN:
8 the control means causes an increase or
9 alternatively no change in the power take-
10 off.

11

12 Preferably the control means repeats the above steps
13 to continue adjusting the power take-off to ensure
14 that the power take-off is always maximised to the
15 power available to the wind turbine which is
16 dependent on the local wind speed at the rotor
17 plane.

18

19 According to a fifth aspect of the invention there
20 is provided a wind turbine according to the second
21 aspect comprising means for reducing the operating
22 vibrations caused by harmonic resonance within the
23 turbine, tower and mounting structure.

24

25 Preferably the wind turbine is provided with a
26 nacelle damping system. The nacelle damping system
27 according to the invention will help to isolate the
28 vibrations in the generator and turbine from the
29 tower.

30

31 Preferably the wind turbine is provided with
32 mounting brackets for mounting the turbine on a

1 surface, the brackets having a sandwich construction
2 of visco-elastic materials and structural materials.

3

4 The mounting means can be of any cross-sectional
5 shape, but is typically tubular. Preferably, the
6 tower contains one or more cores of flexible
7 material, such as rubber, with sections with a
8 reduced diameter, which are not in contact with the
9 tower's inner radial surface. These reduced
10 diameter sections alternate with normal sized
11 sections, which are in contact with the tower's
12 inner surface.

13

14 This serves to absorb vibrations in the tower
15 through the energy dissipated in the flexible core
16 before they reach the mounting brackets. The rubber
17 core thereby acts to control the system's resonant
18 frequency out-with the turbine driving frequency by
19 absorption of a range of vibration frequencies. By
20 altering the cross-sectional shape and length of
21 each of the reduced diameter sections, the system
22 can be "tuned" to remove a range of vibration
23 frequencies from the mounting structure.

24

25 The sandwich mounting brackets compliment the
26 mounting means core design and suppress vibrations
27 that come from the nacelle. The nacelle itself
28 supports the generator through bushes designed to
29 eliminate the remaining frequencies. These three
30 systems act as a high/low pass filter where the only
31 frequencies that are not attenuated are those out-
32 with the operating range of the turbine.

1

2 Embodiments of the present invention will now be
3 described with reference to drawings wherein:

4

5 Figs 1A and 1B show schematic views of two
6 embodiments of the wind turbine according to the
7 present invention;

8

9 Figs 2A and 2B show top views of two embodiments of
10 the rotor and the furling device of the wind turbine
11 according to Figs 1A and 1B respectively;

12

13 Fig 3 shows in detail an embodiment of one boom of
14 the furling device according to the present
15 invention;

16

17 Fig 4 shows the connection of the boom according to
18 Fig 3 through the nacelle;

19

20 Figs 5A and 5B show the connection of the tip of the
21 boom to the tail fin;

22

23 Fig 6 shows a schematic overview of a heating device
24 for heating water which is adapted to be coupled to
25 a wind turbine according to the present invention;

26

27 Fig 7 shows diagrammatically the working of the
28 control system of the heating device according to
29 Fig 6;

30

31 Figs 8A, 8B and 9A, 9B show a further embodiment of
32 a heating device for heating water, which is adapted

1 to be connected to the wind turbine according to the
2 present invention;

3

4 Fig 10 shows a cross-sectional view of the mounting
5 means for the wind turbine according to the present
6 invention, wherein the interior is provided with a
7 vibration damping core;

8

9 Figs 11 and 12 show a cross-sectional view of the
10 mounting means according to Fig 10 as alternative
11 embodiments for the vibration damping core;

12

13 Fig 13 shows a schematic block diagram of a wind
14 turbine system in accordance with the fourth aspect
15 of the invention; and

16

17 Fig 14 shows a schematic block diagram of a wind
18 turbine system in accordance with the fifth aspect
19 of the invention.

20

21 In Figs 1A and 1B are shown possible embodiments of
22 the wind turbine 10,110 according to the present
23 invention is shown. The wind turbine 10,110
24 comprises a rotor 20,120 having a core 25,125 and
25 radial blades 30,130 extending from the core 25,125
26 towards the outer tip 31 of the blades 30,130. The
27 rotor comprises a radial aerofoil 21,121, attached
28 to and encircling the rotor blades 30,130. The
29 rotor 20,120, by means of the core 25,125, is
30 rotationally fixed to a nacelle 41,141. The rotor
31 20,120 is able to rotate about the rotational axis
32 26. The nacelle 41,141 is rotationally mounted on

1 top of mounting means 40. The mounting means 40
2 allow the wind turbine 10,110 to be fixed on a
3 support (not shown). The nacelle 41,141 moreover is
4 provided with a furling mechanism 50,150. The
5 furling mechanism 50,150 comprises a first boom
6 51,151 and a second boom 52,152. The booms
7 51,151;52,152 and their respective ends thereof are
8 provided with tail fins 53,153;54,154.

9
10 The furling mechanism 50,150 has two functions. The
11 first function is to keep the rotational axis 26 of
12 the rotor 20,120 essentially parallel to the
13 momentaneous direction of the airflow. In Fig 1 the
14 airflow is schematically indicated by means of
15 arrows 15. The second function of the furling
16 device 50,150 is to rotate the rotor 20,120 out of
17 the wind when the wind velocity exceeds the output
18 power requirements of the wind turbine or endangers
19 the system's integrity, in order to protect the wind
20 turbine 10,110 against unacceptably high loads.
21 The construction and the working of the furling
22 mechanism will be clarified below, with reference to
23 Figs 2A, 2B, 3, 4, 5A and 5B.

24
25 It is to be understood that whilst the remaining
26 description relates to the embodiment of Fig 1A, the
27 description applies equally to the embodiment of Fig
28 1B.

29
30 As shown in Fig 1, the radial aerofoil 21 is
31 attached to and encircles the turbine blades 30.
32 The radial aerofoil 21 will create a slight venturi

1 effect near the blade tips where the resulting
2 increase in air velocity has the largest effect on
3 the power output of the turbine. This increases the
4 overall efficiency of the turbine 10, which
5 compensates for the slight increase in weight and
6 aerodynamic drag caused by the addition of the
7 aerofoil 21. The aerofoil will also create a more
8 laminar flow along the rotor blades. This is
9 important since the airflow on a roof typically is
10 turbulent. A further advantage is the fact that the
11 presence of the radial aerofoil 21 will increase the
12 mechanical strength of the rotor 20, allowing more
13 efficient aerofoil section to each blade 30. A
14 further advantage is the fact that the presence of
15 the radial aerofoil 21 results in a reduction in the
16 acoustic emissions (noise) from the spinning turbine
17 rotor blades 30 due to the fact that noise including
18 aerodynamic vortex shedding is eliminated or
19 reduced. The presence of the radial aerofoil 21
20 also helps to reduce the effect of turbulent airflow
21 through the rotor plane, and in this way also
22 assists in reducing the acoustic emissions.

23
24 In Fig 1 it can be seen that the design of the blade
25 30 is such that the outer tips 31 of the blade 30
26 are in essence perpendicular to the rotational axis
27 26.

28
29 The outer tips 31 of the blade are connected near
30 the leading edge 22 of the aerofoil 21. The number
31 of blades 30 may be varied. The aerofoil 21 may be

1 positioned to extend in an upstream or downstream
2 orientation with respect to the blades 30.

3

4 In Fig 2 a top view is shown of the rotor 20 and the
5 furling device 50 of the wind turbine 10 according
6 to Fig 1. The furling device 50 comprises booms
7 51,52 each provided with a tail fin 53,54 at the end
8 thereof. The airflow 15 will exert a certain
9 pressure on the tail fins 53,54. The tail fins will
10 balance and stabilise the position of the rotor 20
11 with respect to the direction of the airflow 15.
12 When the direction of the airflow 15 changes the
13 resulting pressure on the tail fins 53,54 will also
14 change. The resulting force will cause the rotor 20
15 to rotate in order to maintain the direction of the
16 airflow 15 in essence in line with the rotational
17 axis 26 of the rotor 20. During normal furling the
18 presence of the aerofoil 21 will reduce vibrations
19 caused by imbalanced blade tip vortex shedding.
20 This is achieved in that the aerofoil will act to
21 divert the airflow from the blade tips during
22 furling.

23

24 The furling device 50 according to the present
25 invention not only maintains an optimal angle
26 between the rotor 20 and the airflow 15, but in
27 addition acts to protect the turbine 20 during
28 excessively high wind loadings. The furling device
29 50 is designed to rotate the turbine (rotor) 20,
30 about axis 42, out of the airflow when the wind
31 velocity exceeds the output power requirements of
32 the turbine or when the wind loading compromises the

1 integrity of the rotor 20 or other turbine
2 components. As shown in Fig 2, the tail fins 53,54
3 form a wedge pointing into, out of substantially
4 parallel to the wind. Excessive wind loadings will
5 make the tail fins 53,54 move and/or rotate with
6 respect to the nacelle 41. Preferably one of the
7 fins has no travel or limited travel, causing the
8 rotor 20 to furl (or rotate) about axis 42 as the
9 second fin continues to rotate under high airflow
10 velocities. It means that the furling mechanism 50
11 according to the present invention under moderate
12 wind velocity will keep the rotor 20 in a stable
13 condition and at a preferred angle with respect to
14 the airflow 15. Only after exceeding a
15 predetermined wind velocity, the same furling device
16 50 will cause the rotor 20 to rotate out of the wind
17 in order to protect the integrity thereof.

18
19 The construction of the furling device 50 according
20 to the present invention causes the furling device
21 to act non-linearly in relation to the wind
22 velocity. The furling device 50 limits the
23 turbine's susceptibility to gusts and turbulence.
24 Light gusts will not be able to move the rotor out
25 of the wind. The safety function of the furling
26 device 50 will only operate in high wind situations
27 in order to protect the turbine and a respective
28 generator.

29
30 As shown in Fig 2 the booms 51 and 52 extend from
31 the nacelle to the tail fins, in the downwind
32 direction of the rotor 20. The respective tail fins

1 53 and 54 are positioned essentially in line with
2 the exterior dimensions of the rotor 20. The
3 construction of the furling device 50 according to
4 the present invention enables a compact construction
5 and does not necessitate free space behind the
6 nacelle 41. That means that the design of this
7 furling system allows the overall length of the
8 turbine to be considerably reduced when compared to
9 existing wind turbines.

10

11 In Figs 3 and 4 the first embodiment of the boom 51
12 and respective tail fin 53 is shown. The arrows
13 indicate the movement of the boom 51 with respect to
14 the nacelle 41. The angle between the rotation axis
15 26 of the rotor (not shown) and the tail fin 53 is
16 changed by use of a hinge 60 located at the base of
17 the boom 51. As shown in Fig 4, the boom 51 is held
18 at a fixed angle to axis 26 by a coil spring 61.
19 When the wind loading on the fin 53 is sufficiently
20 large, the boom 51 and the fin 53 rotate against the
21 retaining force of the coil spring 61, causing an
22 out of balance aerodynamic loading on the rotor 20.
23 This out of balance force will cause the nacelle to
24 rotate about its mounting axis 42 (see Fig 1). It
25 should be noted that the coil spring 61 as shown in
26 Fig 4 is simply for explanatory purposes and any
27 type of spring could be used in the hinge 60.

28

29 In Fig 5A an alternative embodiment is shown wherein
30 the rotation of the furling fin takes place about a
31 hinge 70 located at the outer tip of the boom. In a
32 further preferred embodiment, the hinge is a sprung

1 hinge 170 as shown in Fig 5B. As shown in Fig 5
2 clockwise rotation of the fin 53 at the hinge 70 is
3 limited by an end stop 71. The anti-clockwise
4 rotation of the fin 53 is restrained by the reaction
5 of a coil spring (not shown) or the sprung hinge
6 170. When the speed of the airflow 15 increases to
7 a level at which furling is required, the retaining
8 force of the spring in the hinge 70 or the sprung
9 hinge 170 is overcome and the fin 53 (or in the
10 alternative preferred embodiment the fin 154) will
11 rotate. This causes an out of balance aerodynamic
12 loading on the rotor. This out of balance force
13 will again cause the nacelle to rotate about its
14 mounting axis 42, until the aerodynamic forces on
15 the turbine are in equilibrium. The non-linear
16 furling mechanism 50 according to the present
17 invention will keep the turbine windward and stable
18 until the wind velocity compromises the systems
19 safety and the turbine is progressively yawed from
20 the wind. The furling device 50 therefore reduces
21 constant yawing of the turbine during gusts, which
22 would otherwise create unwanted oscillations and
23 turbine blade noise.

24

25 It is to be understood that whilst there is
26 described embodiments whereby the hinging feature is
27 located at extreme ends of the boom 51,52, the hinge
28 could be provided at any point along the boom 51,52.

29

30 Additionally or alternatively, the fin 53 or 54 can
31 be arranged to fold along their horizontal axis thus
32 causing the imbalance in that way.

1
2 The actual furling angle necessary to protect the
3 wind turbine can be limited because of the presence
4 of the aerofoil 21. A certain furling of the rotor
5 20 will result in aerodynamic stalling along the
6 foil 21 and/or blades 30. As soon as the stalling
7 starts, the power of the wind flow 15 on the rotor
8 20 will drop.

9
10 In Fig 6 a schematic overview of a wind turbine
11 heating system is shown. The wind turbine heating
12 system comprises a first water reservoir 118. In
13 the water reservoir one or more electric heating
14 elements 114 are provided. The electrical heating
15 elements 114 are coupled with the wind turbine 10
16 via a control unit 116. The electrical current
17 generated by the wind turbine 10 will be directed to
18 the electrical heating elements 114 in order to heat
19 up the water contained in reservoir 118. While the
20 efficiency of the heat transfer for electric heating
21 elements may be considered to be near 100%,
22 operating an element at a lower power input than
23 that for which it was designed results in a lower
24 element temperature. The nature of wind power is
25 such that the power output will usually be
26 considerably below the overall rated power of the
27 heating system. As such, it is necessary to use
28 heating elements 114 with an appropriate power
29 rating.

30
31 The water reservoir 118 is designed to store warm
32 water, prior to use. The reservoir 118 may be a

1 cylinder manufactured from copper alloy but any
2 shape of cylinder or any material may be used such
3 as enamelled steels and plastics. Steel cylinders
4 are better suited to higher pressure applications,
5 while copper is attractive due to its inherent
6 corrosion resistance and the associated long
7 service-life. For vented systems and their
8 associated lower cylinder pressure, copper cylinders
9 are well suited.

10

11 When, using the system according to Fig 6, all of
12 the water in the reservoir 118 has been heated to
13 the maximum allowable temperature, the control unit
14 116 will no longer allow the heating elements 114 to
15 dissipate power into the water reservoir 118. That
16 means that the power generated by the wind turbine
17 has to be "dumped" elsewhere (dump element). As
18 long as the wind turbine 10 is generating
19 electricity, it is essential that there is a means
20 of dissipating the electrical energy at all times.

21

22 This dump element is activated by the electronic
23 control system turning the said dump element "on"
24 when the power available from the wind exceeds the
25 power take-off due to a loss or reduction of
26 electrical load caused by the switching off,
27 reduction or separation of the said electrical load.
28 The said element is triggered by an increased rotor
29 speed above a defined "dump on" rotor speed caused
30 by the imbalance of wind turbine rotor torque and
31 wind turbine generator torque. The said wind
32 turbine rotor torque is dependent on wind speed and

1 the said wind turbine generator torque is dependent
2 on the electrical load. The said dump element
3 serves to increase the wind turbine generator torque
4 above the wind turbine rotor torque reducing the
5 wind turbine rotor speed until it approaches or
6 reaches a stall. The generator torque is then
7 reduced by releasing the dump load when the wind
8 turbine rotor speed falls below a defined "dump off"
9 rotor speed. The said "dump on" and "dump off"
10 rotor speeds are defined proportionally to the power
11 take-off and electrical load.

12
13 Water heated in a hot water reservoir 118 with
14 elements 114 will tend to form stratified layers.
15 The temperature within each layer will not vary much
16 as heat will be spread by conduction and convection.
17 A high temperature gradient exists between layers.
18 This phenomenon would be useful in a situation where
19 several heating elements are used, as the top layer
20 could be heated up, and then left undisturbed by the
21 convection below it as lower layers were
22 subsequently heated.

23
24 It should be noted that the heating element design
25 described herein could be used with or without a
26 mains connection in tandem. The mains connection
27 would allow the immersion heating element (or a
28 dedicated mains element) to provide energy when none
29 is available from the wind turbine.

30
31 With respect to the efficiency of the wind turbine,
32 the power extracted from the wind by the rotor

1 should be limited to approximately 60% (59,6%).
2 Because of the fact that the wind turbine according
3 to the present invention can be operated in
4 turbulent airflows, the efficiency of the wind
5 turbine according to the present invention can be
6 improved by adding a new control system.

7
8 Fig 7 schematically shows the working of the control
9 system according to the present invention. First,
10 the load on the wind turbine is near a predetermined
11 starting level (L0). Multiple measurements of rotor
12 speed are made after defined time periods. These
13 measurements are used to calculate the first, second
14 and third order values to the said increase or
15 decrease on power take-off. The said first, second
16 and third order values determining a change in the
17 existing power take-off and the amount of power
18 taken from the wind turbine is again adjusted.

19
20 The method of controlling the level of power taken
21 from a wind turbine comprises the following steps
22 taken by the control means:

- 23 (a) increasing or decreasing the power take-off
24 from the wind turbine by a small amount;
- 25 (b) temporarily setting the level of power take
26 -off;
- 27 (c) after a predetermined time period, taking a
28 number of measurements of the rotor speed;
- 29 (d) calculating the first, second and third
30 order values, namely speed,
31 acceleration/deceleration and rate of change
32 of acceleration/deceleration respectively,

1 to the said increase or decrease in power
2 take-off;

3 (e) adjusting the power taken from the wind
4 turbine in response to the calculation.

5

6 Steps (b) to (e) are then repeated continuously.

7

8 The control means uses the following logic to
9 determine the adjustment:

- 10 (a) IF: there is a positive second order rotor
11 speed response (acceleration) and an
12 increasing rate of said acceleration
13 (positive third order response) of the rotor
14 speed; THEN: the control means causes an
15 increase in the power take-off; OR
16 (b) IF: there is a positive second order rotor
17 speed response (acceleration) and decreasing
18 rate of said acceleration (negative third
19 order response) of the rotor speed; THEN:
20 the control means causes an increase or
21 alternatively no change in the power take-
22 off; OR
23 (c) IF: there is a negative second order rotor
24 speed response (deceleration) and increasing
25 rate of said deceleration (positive third
26 order response) of the rotor speed; THEN:
27 the control means causes a reduction in the
28 power take-off; OR
29 (d) IF: there is a negative second order rotor
30 speed response (deceleration) and decreasing
31 rate of said deceleration (negative third
32 order response) of the rotor speed; THEN:

1 the control means causes an increase or
2 alternatively no change in the power take-
3 off.

4
5 The control means repeats the above steps to
6 continue adjusting the power take-off to ensure that
7 the power take-off is always maximised to the power
8 available to the wind turbine, or yield, which is
9 dependent on the local wind speed at the rotor
10 plane.

11
12 Because of the fact that the wind velocity on the
13 rotor will be continuously varying, the time
14 interval for increasing and decreasing the amount of
15 load on the wind turbine will typically be in the
16 ranges of milliseconds to tens of seconds.

17
18 The efficiency of the wind turbine heating system
19 can be further increased when using an alternative
20 water reservoir 128 as shown in Fig 8. The water
21 reservoir 128 is provided with an electrical heating
22 element 124. The heating element 124 is covered,
23 over a substantive length thereof, by means of an
24 enclosing tube 125. The bottom end 126 of the tube
25 125 is open. This enables water to flow in between
26 the exterior of the heating device 124 and the
27 interior of the tube 125. As soon as current passes
28 through the element 124 the electrical energy will
29 be converted into heat energy and this heat energy
30 is then transferred to the water. The water film
31 directly enclosing the heating element 124 will be
32 heated and, due to natural convection, will flow

1 towards the top of the reservoir 128 and is
2 prevented from diffusing radially into the reservoir
3 128. Because of the presence of the tube 125 the
4 heated water is directed towards a warm water zone
5 130 in a top part of the reservoir 128. The heat
6 generated by the heating element 124 therefore is
7 concentrated in the top part of the reservoir 128
8 and is prevented from diffusing radially into the
9 reservoir 128. This will limit the time necessary
10 to heat up water to a preferred temperature thus
11 reducing the energy consumption of thereof.

12

13 As soon as the power generated by the wind turbine
14 is increased, the amount of heat transferred to the
15 water in the reservoir 128 is also increased. This
16 means that the flow of heated water towards the top
17 part of the reservoir 128 will increase, resulting
18 in mixing the thermally stratified layers, and in an
19 enlarged warm water area 130. This effect is shown
20 in Fig 9. Because of the construction of the
21 reservoir 128, power no longer has to be "dumped".
22 The use of the reservoir 128 is especially suitable
23 for a wind turbine, because of the fact that the
24 nature of wind power is such that the power output
25 will usually fluctuate and moreover will be below
26 the overall rated power of the heating system.

27

28 During normal operation of a wind turbine according
29 to the invention, vibrations are caused by harmonic
30 resonance within the turbine, tower and mounting
31 structure. These come from blade imbalances, due to
32 deformation during operation, aerodynamically

1 induced vibrations or mechanically induced
2 vibrations in the rotor, generator or other turbine
3 components. Eliminating resonance in micro-wind
4 turbines is especially difficult as they operate
5 through a wide range of turbine tip-speeds. The
6 design described below reduces the operating
7 vibrations by controlling the turbine tip-speeds so
8 that they remain outside natural resonant
9 frequencies, and through novel vibration absorption
10 measures.

11
12 Mounting a horizontal axis wind turbine on a
13 building structure requires the damping of critical
14 frequencies and the moving of harmonics beyond the
15 system operating frequencies. The damping system on
16 the rooftop wind turbine is integrated into the
17 design of the mounting means and nacelle of the
18 turbine. These vibration absorbing systems work
19 together to create a silent running rooftop turbine.

20
21 The novel wind turbine mounting bracket uses a
22 sandwich construction of viscoelastic materials and
23 structural materials.

24
25 The mounting means tower contains an innovative
26 core, typically of rubber, which has some sections
27 which have a reduced cross-sectional area and are
28 not in contact with the mounting means' inner
29 surface and some sections which are. This serves to
30 absorb vibrations in the mounting means through the
31 energy dissipated in the rubber core before they
32 reach the mounting bracket. The rubber core also

1 acts to force the system's resonant frequency above
2 the turbine driving frequency.

3
4 In Fig 10 a possible embodiment of the interior of
5 the mounting means is shown, in cross-section. In
6 this embodiment, the mounting means is tubular in
7 cross-section. The mounting means 40 comprises a
8 hollow core wherein a cylindrical core element 90 is
9 present. The core element 90 in the middle thereof
10 is provided with a hollow section 91 in order to
11 allow elements such as a power line to be guided
12 through the interior of the core element 90. The
13 core element 90 is provided with sections 92 with an
14 exterior diameter corresponding substantially to
15 the interior diameter of the mounting means 40.
16 These sections alternate with sections 93 that have
17 a reduced diameter and are not in contact with the
18 mounting means' 40 inner radial surface. The
19 sandwich mounting bracket together with the mounting
20 means core design suppresses vibrations in the
21 system. The main sources for those vibrations are
22 vibrations transmitted from the wind turbine to the
23 building, and the aerodynamic turbulence around
24 obstacles, which decreases power output but more
25 importantly shortens the working life of the wind
26 turbine.

27
28 In Fig 11 an alternative embodiment of the interior
29 of the mounting means is shown, in cross-section.
30 The hollow core of the mounting means 40 is provided
31 with a core element 94. The core element 94 in the
32 middle thereof is provided with a hollow section 91.

1 The core element 94 is provided with sections 92
2 with an exterior diameter corresponding
3 substantially to the interior diameter of the
4 mounting means 40. These sections alternate with
5 sections 93 that have a reduced diameter and are not
6 in contact with the mounting means' 40 inner radial
7 surface. When comparing Figs 10 and 11 it will be
8 clear that the shape of the recesses in respective
9 core elements 90 and 94 differs. It should be noted
10 that Figs 10 and 11 are for illustration purposes
11 only. Alternative embodiments for the core elements
12 are also possible.

13
14 Fig 12 shows a further embodiment of the interior of
15 the mounting means 40. As shown in Fig 12, the
16 interior of the mounting means 40 comprises several
17 core elements 95, which are inserted in the mounting
18 means wherein a first element 95 abuts an adjacent
19 element 95. In the example of Fig 12 the shape of
20 the recesses in the respective elements 95 again
21 differs from the embodiments according to Fig 10 and
22 Fig 11.

23
24 In a wind turbine noise comes from two areas,
25 aerodynamic sources and mechanical sources.
26 Aerodynamic noise is radiated from the blades,
27 originating due to the interaction of the blade
28 surfaces with turbulence and natural atmospheric or
29 viscous flow in the boundary layer around the
30 blades. Mechanical noise is due to the relative
31 motion of mechanical components and the dynamic

1 response among them. This effect may be magnified
2 if the nacelle, rotor and tower transmit the
3 mechanical noise and radiate it, acting as a
4 loudspeaker. Two types of noise problem exist: air
5 borne noise which is noise which is transmitted
6 directly from the component surface or interior into
7 the air, and structure borne noise which is
8 transmitted through the structure before being
9 radiated by another component.

10

11 The turbine mounting and mounting means are designed
12 to push the resonant frequency of the whole
13 structure out-with the operation vibration
14 frequencies caused by blade unbalances, aerodynamic
15 induced vibrations, mechanical induced vibrations
16 and deformations. The mounting contains a damping
17 system which eliminates vibrations.

18

19 As shown in Fig 13, the wind turbine 10 can form
20 part of a wind turbine system 200 which can be
21 connected to a stand alone or grid-tie inverter 201
22 for connection to local power infrastructure, or to
23 a local or embedded grid connection 202. The system
24 200 can also be provided with a rectifier 203 which
25 rectifies the power output from the wind turbine 10
26 and feeds the rectified power to an electronic
27 controller 204 (as described in previous
28 embodiments) which can either "dump" excess load 205
29 (which may be done as described above for other
30 embodiments by way of an external resistive load) or
31 supply power to the inverter 201. In this way the
32 wind turbine system 200 can be utilised to feed

1 power to power infrastructure such as a local grid
2 network or the national grid.

3

4 As shown in Fig 14, the wind turbine 10 can form
5 part of a wind turbine system 300 which can be
6 connected to an energy storage device 301. The
7 storage device may be in the form of battery packs,
8 or any other suitable form of energy storage device.
9 The system 300 can also be provided with a rectifier
10 303 which rectifies the power output from the wind
11 turbine 10 and feeds the rectified power to an
12 electronic controller 304 (which may be done as
13 described above for other embodiments by way of an
14 external resistive load) which can either "dump"
15 excess load 305 (which may be done as described
16 above for other embodiments) or supply power to the
17 storage device 301. In this way the wind turbine
18 system 200 can be utilised to feed power to a
19 storage device for later use.

20

21 Modifications and improvements may be made to the
22 foregoing without departing from the scope of the
23 invention.

1 CLAIMS

2

3 1. A rotor for a wind turbine comprising a plurality
4 of radial blades and a ring-shaped aerofoil diffuser
5 connecting the outer tips of the blades.

6

7 2. A rotor according to claim 1, wherein the
8 aerofoil diffuser extends downstream from the outer
9 tips of the blades.

10

11 3. A rotor according to either preceding claim,
12 wherein the outer tips of the blades are connected
13 to the diffuser at or near to the leading edge of
14 the diffuser.

15

16 4. A rotor according to any preceding claim, wherein
17 the aerofoil diffuser tapers outwards from the outer
18 tips of the blades to form a substantially frusto-
19 conical diffuser.

20

21 the rotational axis of the frusto-conical diffuser
22 is substantially aligned to the rotational axis of
23 the blades.

24

25 5. A rotor according to claim 1, wherein at least a
26 portion of the aerofoil diffuser extends upstream
27 from the outer tips of the blades.

28

29 6. A rotor according to any preceding claim, wherein
30 the aerofoil diffuser tapers radially outwards as it
31 extends from the upstream end to the downstream end.

32

1 7. A rotor according to any preceding claim, wherein
2 the aerofoil diffuser is shaped such that it
3 inhibits the partly axial and partly radial airflow
4 from the blades, said airflow becoming
5 circumferential when it contacts the aerofoil
6 diffuser.

7
8 8. A rotor according to any preceding claim, wherein
9 the aerofoil diffuser is adapted to inhibit partly
10 axial and partly radial airflow from the outer tips
11 of the blades and divert said airflow to
12 substantially circumferential airflow during normal
13 operation.

14
15 9. A rotor according to any preceding claim, wherein
16 the blades are inclined at an angle relative to a
17 transverse rotor plane perpendicular to the
18 rotational axis of the rotor.

19
20 10. A rotor according to claim 9, wherein the angle
21 of inclination may vary along the length of the
22 blade.

23
24 11. A rotor according to claim 9 or claim 10,
25 wherein the angle of inclination of each blade is
26 greater at an intermediate portion of the blade than
27 at the outer tip of the blade.

28
29 12. A rotor according to any preceding claim,
30 wherein the blades are substantially parallel to the
31 transverse rotor plane at the outer tip of the
32 blades.

1

2 13. A wind turbine comprising a rotor according to
3 claims 1 to 12, further comprising a nacelle and a
4 mounting means adapted to allow rotation of the
5 turbine and rotor about a directional axis
6 perpendicular to the rotational axis, thus allowing
7 the turbine to be oriented in the optimum direction
8 depending on wind conditions.

9

10 14. A wind turbine according to claim 13, further
11 comprising a furling means adapted to rotate the
12 rotor about the directional axis so that the
13 rotational axis is not parallel to the direction of
14 airflow when the airflow speed is greater than a
15 predetermined airflow speed.

16

17 15. A wind turbine according to claim 14, wherein
18 the furling means comprises a non-linear furling
19 means adapted to provide no furling over a first
20 lower range of airflow speed and a varying degree of
21 furling over a second higher range of airflow speed.

22

23 16. A wind turbine according to claims 14 and 15,
24 wherein the furling means comprises at least two
25 tail fins extending downstream of the diffuser.

26

27 17. A wind turbine according to claim 16, wherein
28 the two tail fins are provided diametrically
29 opposite each other.

30

31 18. A wind turbine according to claim 16 or 17,
32 wherein one of the tail fins is a moveable tail fin

1 hingedly mounted for rotation about a tangential
2 hinge line.

3
4 19. A wind turbine according to claim 18, wherein
5 the moveable tail fin may be mounted on a mounting
6 boom and the hinge line may be provided: at the
7 connection point of the mounting boom and the
8 nacelle, so that the mounting boom also rotates; at
9 the connection between the mounting boom and the
10 moveable tail fin so that only the moveable tail fin
11 rotates; or at any point along the length of the
12 mounting boom.

13
14 20. A wind turbine according to claims 18 or 19,
15 wherein the tail fin rotates about a horizontal axis
16 under high winds resulting in a fin which folds
17 about a horizontal axis.

18
19 21. A wind turbine according to claims 18 to 20,
20 wherein the moveable tail fin is rotationally biased
21 by biasing means to an at-rest position in which the
22 leading edge of the moveable tail fin is closer to
23 the axis of rotation of the rotor than the trailing
24 edge of the moveable tail fin, such that the
25 moveable tail fin is angled at an at-rest attack
26 angle to the axis of rotation of the rotor.

27
28 22. A wind turbine according to claim 21, wherein
29 the biasing means is non-linear.

30
31 23. A wind turbine according to claim 21 or 22,
32 wherein the biasing means is adapted to hold the

1 moveable tail fin in the at-rest position until the
2 airflow speed reaches a predetermined speed and is
3 further adapted such that as the airflow speed
4 increases beyond the predetermined speed the
5 moveable fin rotates and the attack angle decreases,
6 resulting in unbalanced aerodynamic loading on the
7 wind turbine, such that the wind turbine rotates
8 about its mounting axis to a furled position.

9

10 24. A wind turbine system comprising:

11 a wind turbine driven generator and means for
12 providing a power output.

13

14 25. A wind turbine system according to claim 24,
15 wherein the system further comprises an electronic
16 control system.

17

18 26. A wind turbine system according to claim 24 or
19 25, wherein the system comprises a dump element
20 comprising one or more energy dissipaters.

21

22 27. A wind turbine system according to claim 26,
23 wherein the energy dissipaters are in the form of
24 resistive elements.

25

26 28. A wind turbine system according to claims 26 or
27 27, wherein the dump element is in the form of a
28 liquid storage vessel having electrical heating
29 elements therein adapted to heat liquid in said
30 storage vessel.

31

1 29. A wind turbine system according to claim 28,
2 wherein the control system may be adapted to supply
3 electrical power to said one or more electrical
4 heating elements when the power from the wind
5 exceeds a predetermined power.
6

7 30. A wind turbine system according to claim 28 or
8 29, wherein the liquid storage vessel is a cold
9 water tank and the liquid is water.
10

11 31. A wind turbine system according to claim 28 or
12 29, wherein the heating element is a radiator.
13

14 32. A wind turbine system according to claim 26,
15 wherein the dump element is activated by the
16 electronic control system when the power available
17 from the wind exceeds the power take-off due to a
18 loss or reduction of electrical load caused by the
19 switching off, reduction or separation of the said
20 electrical load.
21

22 33. A wind turbine system according to claim 32,
23 wherein the dump element is activated when the rotor
24 speed increases above a defined "dump on" rotor
25 speed caused by the imbalance of wind turbine rotor
26 torque and wind turbine generator torque, said wind
27 turbine rotor torque being dependent on wind speed
28 and the said wind turbine generator torque being
29 dependent on the electrical load.
30

31 34. A wind turbine system according to claim 33,
32 wherein said dump element is adapted to increase the

1 wind turbine generator torque above the wind turbine
2 rotor torque reducing the wind turbine rotor speed
3 until it approaches or reaches a stall and is
4 further adapted such that the generator torque is
5 released when the wind turbine rotor speed falls
6 below a defined "dump off" rotor speed, the said
7 "dump on" and "dump off" rotor speeds being defined
8 proportionally to the power take-off.

9

10 35. A wind turbine system according to claims 24 to
11 34, wherein the wind turbine system is provided with
12 a control means adapted to control the level of
13 power taken from the wind turbine.

14

15 36. A wind turbine system according to claim 35,
16 wherein the control system is adapted to increase or
17 decrease the power take-off from the wind turbine by
18 a small amount relative to the total power take-off.

19

20 37. A wind turbine system according to claims 24 to
21 36, wherein the system comprises a wind turbine
22 according to claims 1 to 23.

23

24 38. A wind turbine system according to claims 24 to
25 37, wherein the power output is connected to a
26 heating system further comprising a further liquid
27 storage vessel,

28 one or more electrical heating elements adapted
29 to heat liquid in said further vessel, and

30 control means adapted to control the supply of
31 electricity generated by said generator to said one
32 or more electrical heating elements.

1

2 38. A wind turbine system according to claim 37,
3 wherein the further liquid storage vessel is a hot
4 water tank and the liquid is water.

5

6 39. A wind turbine system according to claim 38,
7 wherein the heating system comprises a plurality of
8 electrical heating elements, and the control means
9 is adapted to supply electrical power to a
10 proportion of the electrical heating elements, the
11 proportion being dependent upon the instantaneous
12 electrical power generated by the generator.

13

14 40. A wind turbine system according to claim 39,
15 wherein the heating element in the further liquid
16 vessel is enclosed by means of a tube, open on the
17 underside thereof and adapted to allow water to flow
18 from beneath the tube towards the heating element.

19

20 41. A wind turbine system according to claim 40,
21 wherein the tube encloses and extends over the
22 entire length of the heating element such that the
23 water near the heating element is heated and will
24 flow upwards due to natural convection, the tube
25 being adapted to enable the formation of different
26 and separate heat zones within the further liquid
27 storage vessel.

28

29 42. A wind turbine system according to claims 24 to
30 41, wherein the power output is connected to a grid-
31 tie inverter or stand alone inverter.

32

1 43. A wind turbine system according to claim 42,
2 wherein the inverter is adapted to supply power to
3 local or grid power infrastructure.

4
5 44. A wind turbine system according to claims 24 to
6 43, wherein the power output is connected to an
7 energy storage system.

8
9 45. A method of controlling the level of power taken
10 from a wind turbine comprising the following steps
11 taken by a control means:

- 12 (a) increasing or decreasing the power take-off
13 from the wind turbine by a small amount;
14 (b) temporarily setting the level of power take
15 -off;
16 (c) after a predetermined time period, taking a
17 number of measurements of the rotor speed;
18 (d) calculating the first, second and third
19 order values, namely speed,
20 acceleration/deceleration and rate of change
21 of acceleration/deceleration respectively,
22 to the said increase or decrease in power
23 take-off;
24 (e) adjusting the power taken from the wind
25 turbine in response to the calculation.

26
27 46. A method according to claim 45, wherein the
28 control means uses the following logic to
29 determine the adjustment:

- 30 (a) IF: there is a positive second order rotor
31 speed response (acceleration) and an
32 increasing rate of said acceleration

1 (positive third order response) of the rotor
2 speed; THEN: the control means causes an
3 increase in the power take-off; OR

4 (b) IF: there is a positive second order rotor
5 speed response (acceleration) and decreasing
6 rate of said acceleration (negative third
7 order response) of the rotor speed; THEN:
8 the control means causes an increase or
9 alternatively no change in the power take-
10 off; OR

11 (c) IF: there is a negative second order rotor
12 speed response (deceleration) and increasing
13 rate of said deceleration (positive third
14 order response) of the rotor speed; THEN:
15 the control means causes a reduction in the
16 power take-off; OR

17 (d) IF: there is a negative second order rotor
18 speed response (deceleration) and decreasing
19 rate of said deceleration (negative third
20 order response) of the rotor speed; THEN:
21 the control means causes an increase or
22 alternatively no change in the power take-
23 off.

24

25 47. A method according to claim 45 or 46, wherein
26 the control means repeats any of the above steps to
27 continue adjusting the power take-off to ensure that
28 the power take-off is always maximised to the power
29 available to the wind turbine which is dependent on
30 the local wind speed at the rotor plane.

31

1 48. A wind turbine according to claims 13 to 23
2 comprising means for reducing the operating
3 vibrations caused by harmonic resonance within the
4 turbine, tower and mounting structure.

5
6 49. A wind turbine according to claim 48, wherein
7 the wind turbine is provided with a nacelle damping
8 system, adapted to at least partially isolate the
9 vibrations in the generator and turbine from the
10 tower.

11
12 50. A wind turbine according to claim 48 or 49,
13 wherein the wind turbine is provided with mounting
14 brackets for mounting the turbine on a surface, the
15 brackets having a sandwich construction of visco-
16 elastic materials and structural materials.

17
18 51. A wind turbine according to claims 48 to 50,
19 wherein the mounting means is tubular.

20
21 52. A wind turbine according to claim 50, wherein
22 the tower contains one or more cores of flexible
23 material, such as rubber, with sections with a
24 reduced diameter, which are not in contact with the
25 tower's inner radial surface, such that the reduced
26 diameter sections alternate with normal sized
27 sections, which are in contact with the tower's
28 inner surface thus serving to absorb vibrations in
29 the tower through the energy dissipated in the
30 flexible core before they reach the mounting
31 brackets.

32

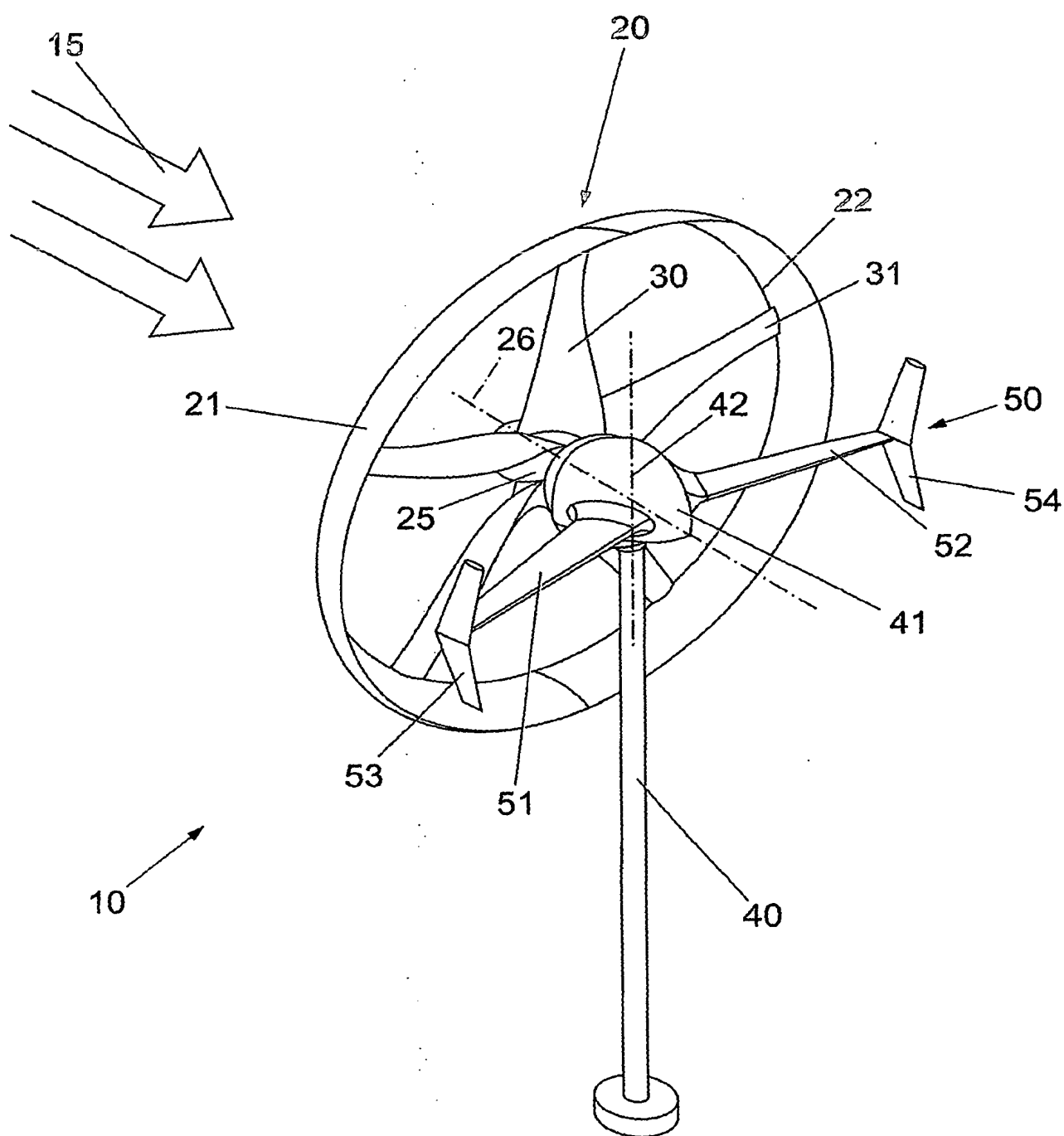
1 53. A wind turbine according to claim 52, wherein
2 the rubber core is adapted to control the system's
3 resonant frequency out-with the turbine driving
4 frequency by absorption of a range of vibration
5 frequencies.

6
7 54. A wind turbine according to claim 53, wherein
8 the cross-sectional shape and length of each of the
9 reduced diameter sections is altered thus "tuning"
10 the system to remove a range of vibration
11 frequencies from the mounting structure.

12
13 55. A wind turbine according to claims 48 to 54,
14 wherein the sandwich mounting brackets compliment
15 the mounting means core design and suppress
16 vibrations that come from the nacelle.

17
18 56. A wind turbine according to claim 55, wherein
19 the nacelle supports the generator through bushes
20 designed to eliminate vibration frequencies.

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*Fig. 1a*

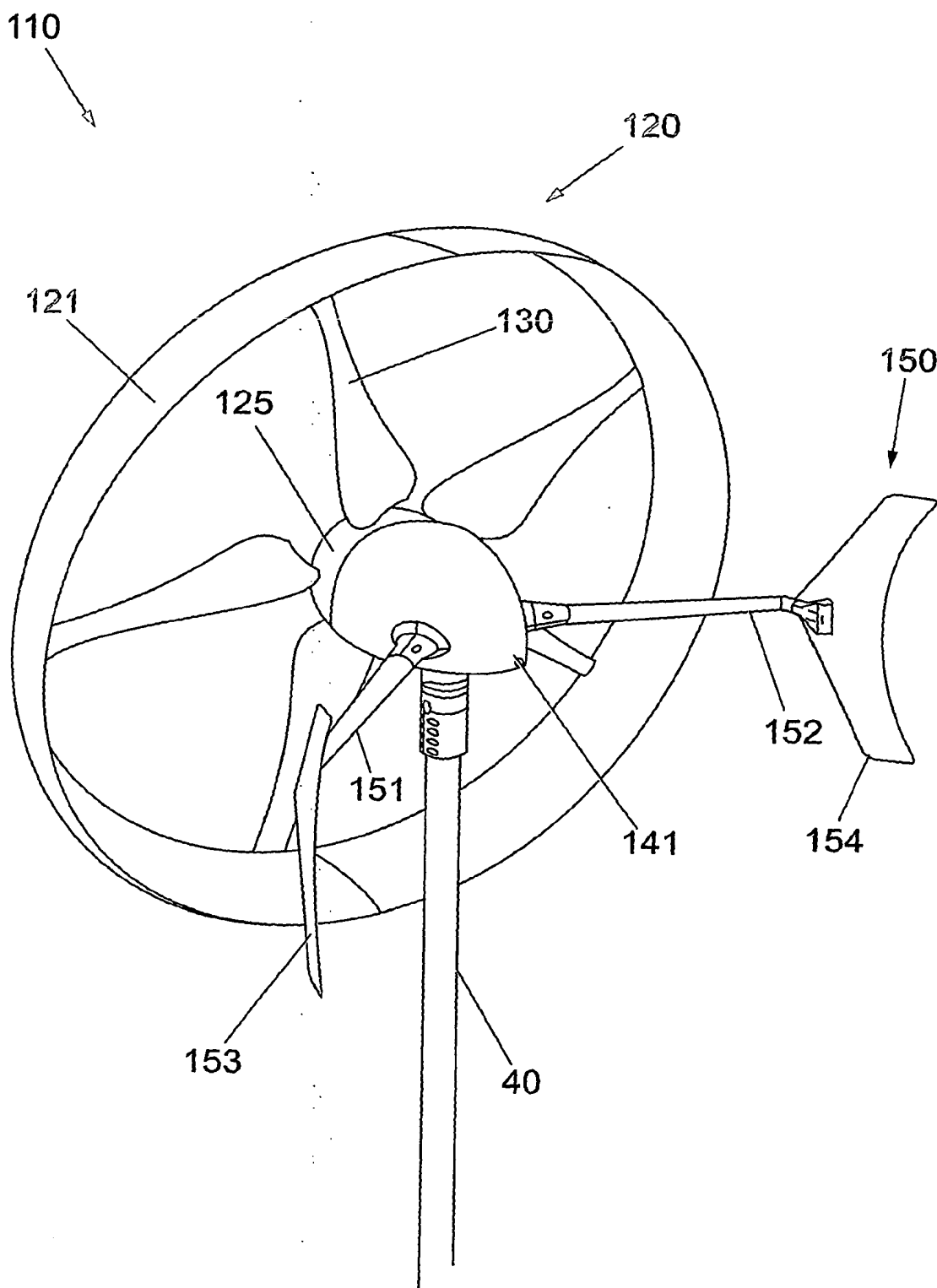
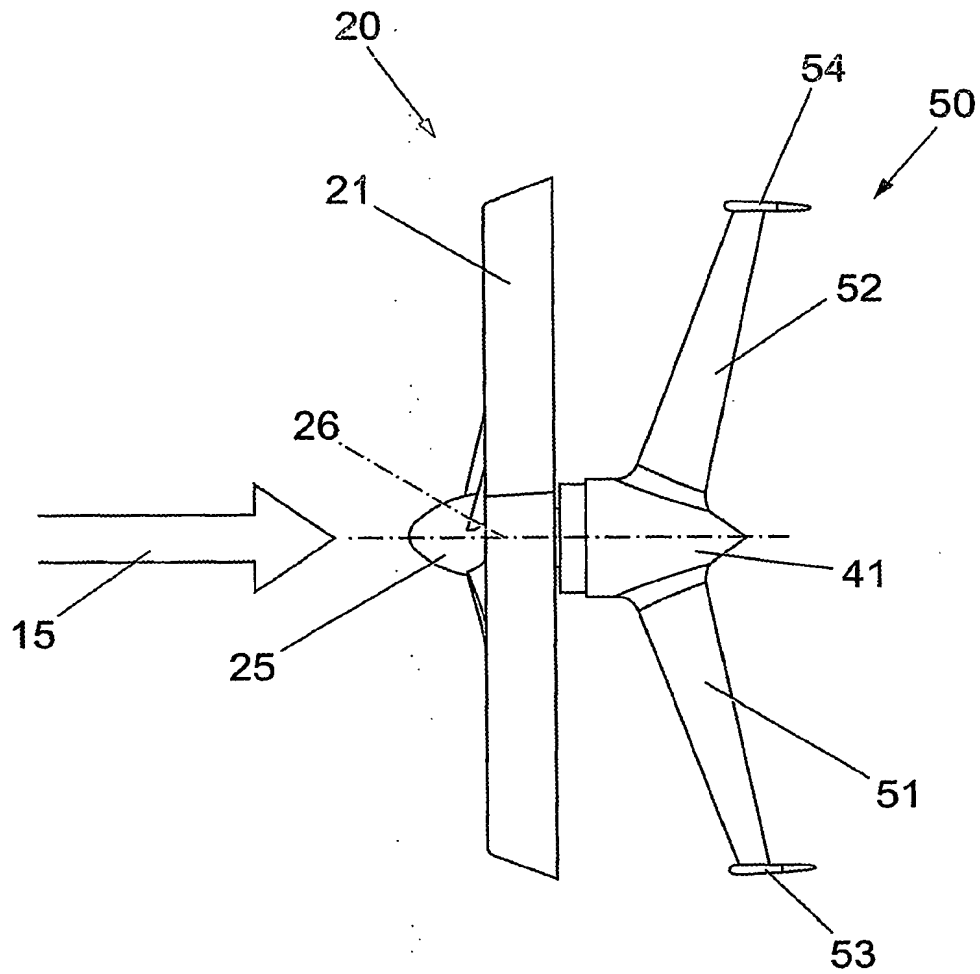
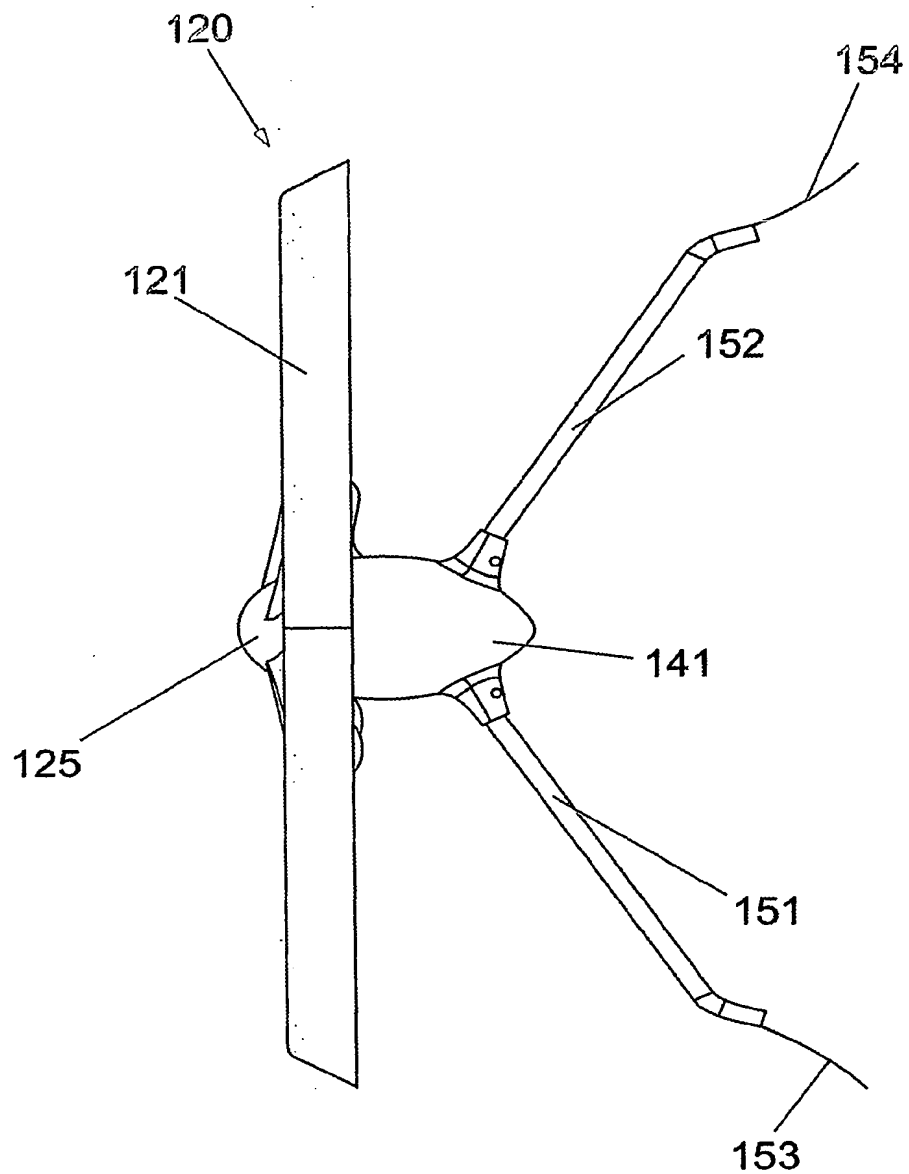


Fig. 1b

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*Fig. 2a*

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*Fig. 2b*

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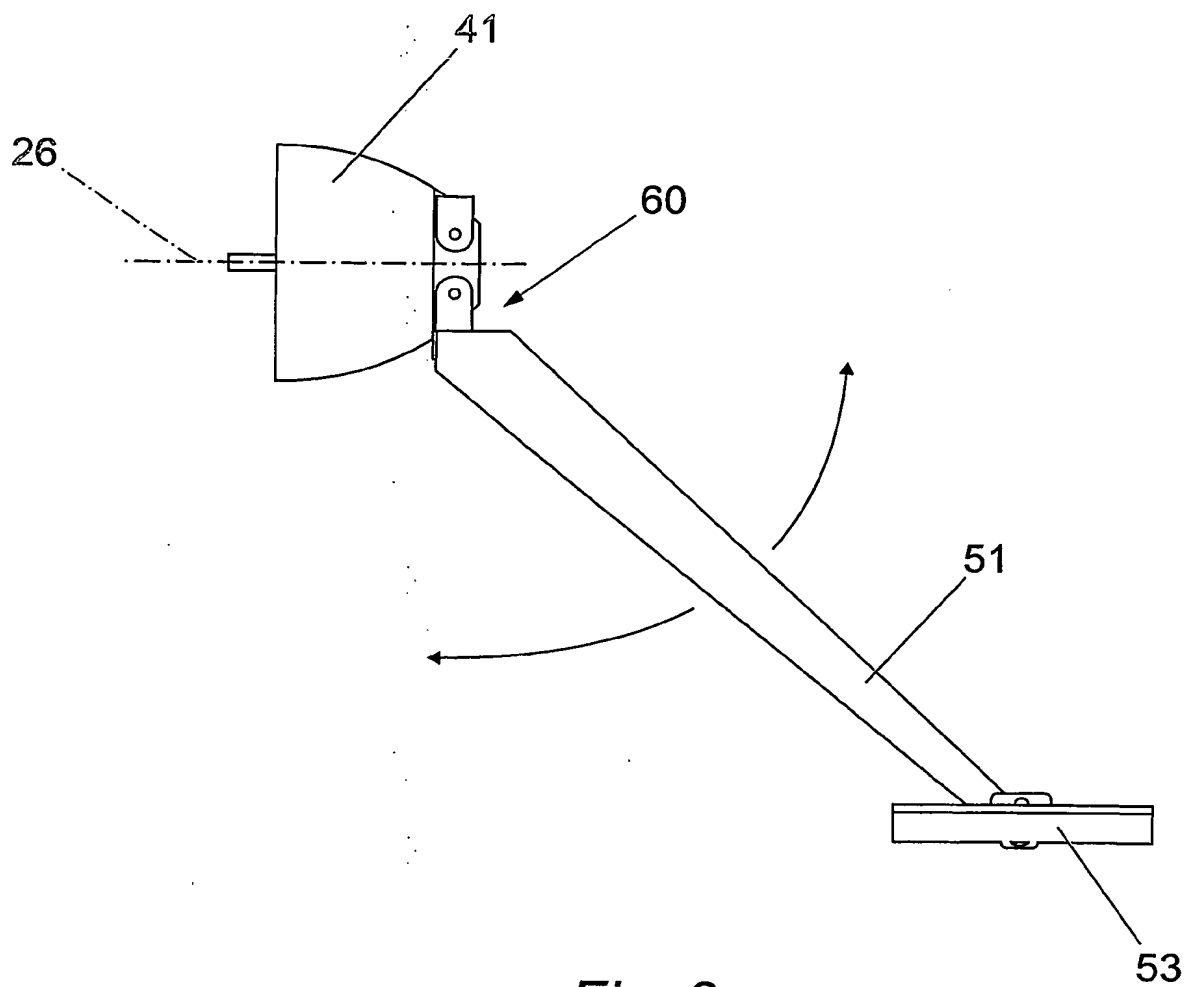


Fig. 3

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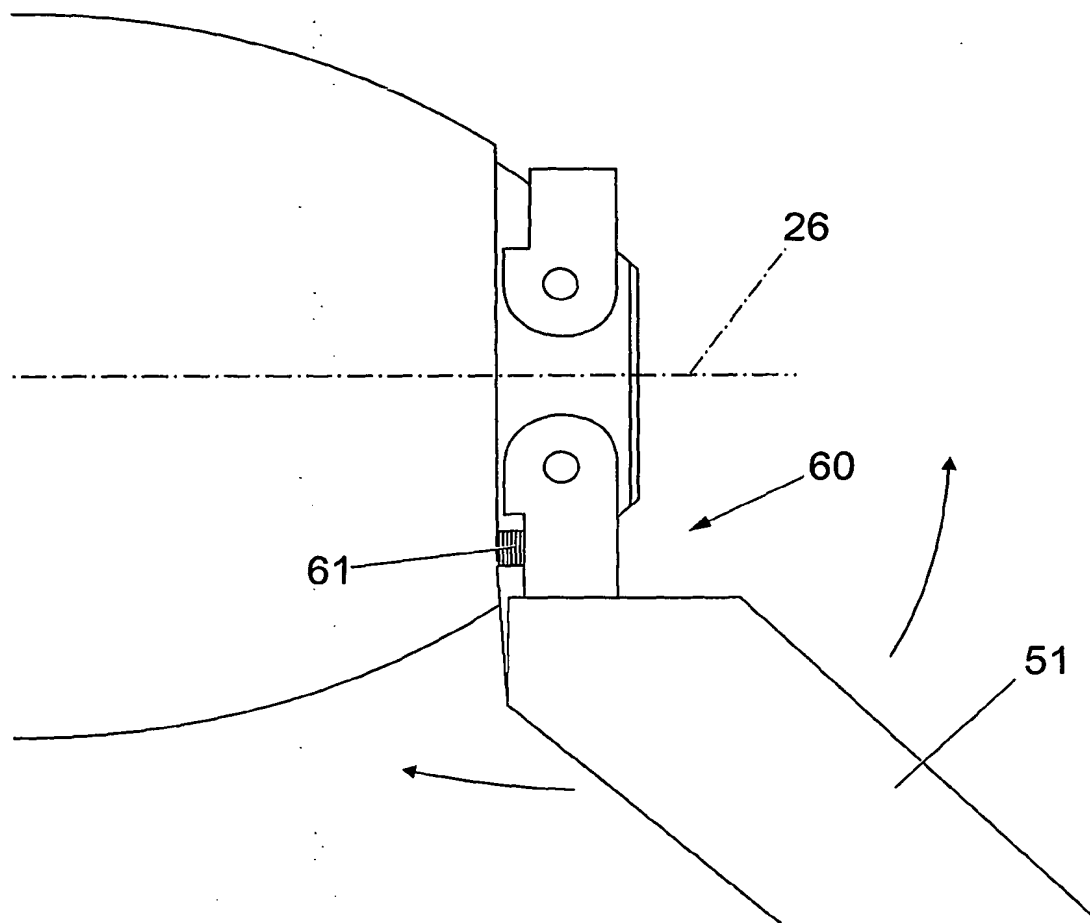
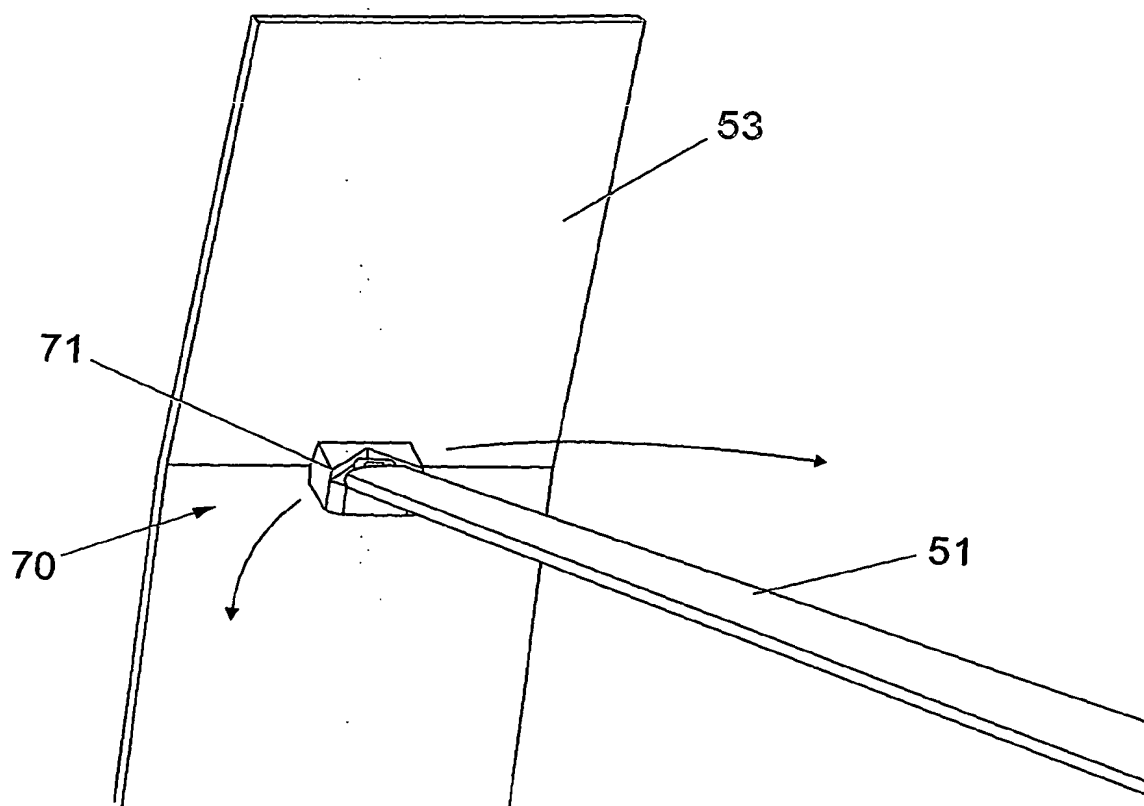
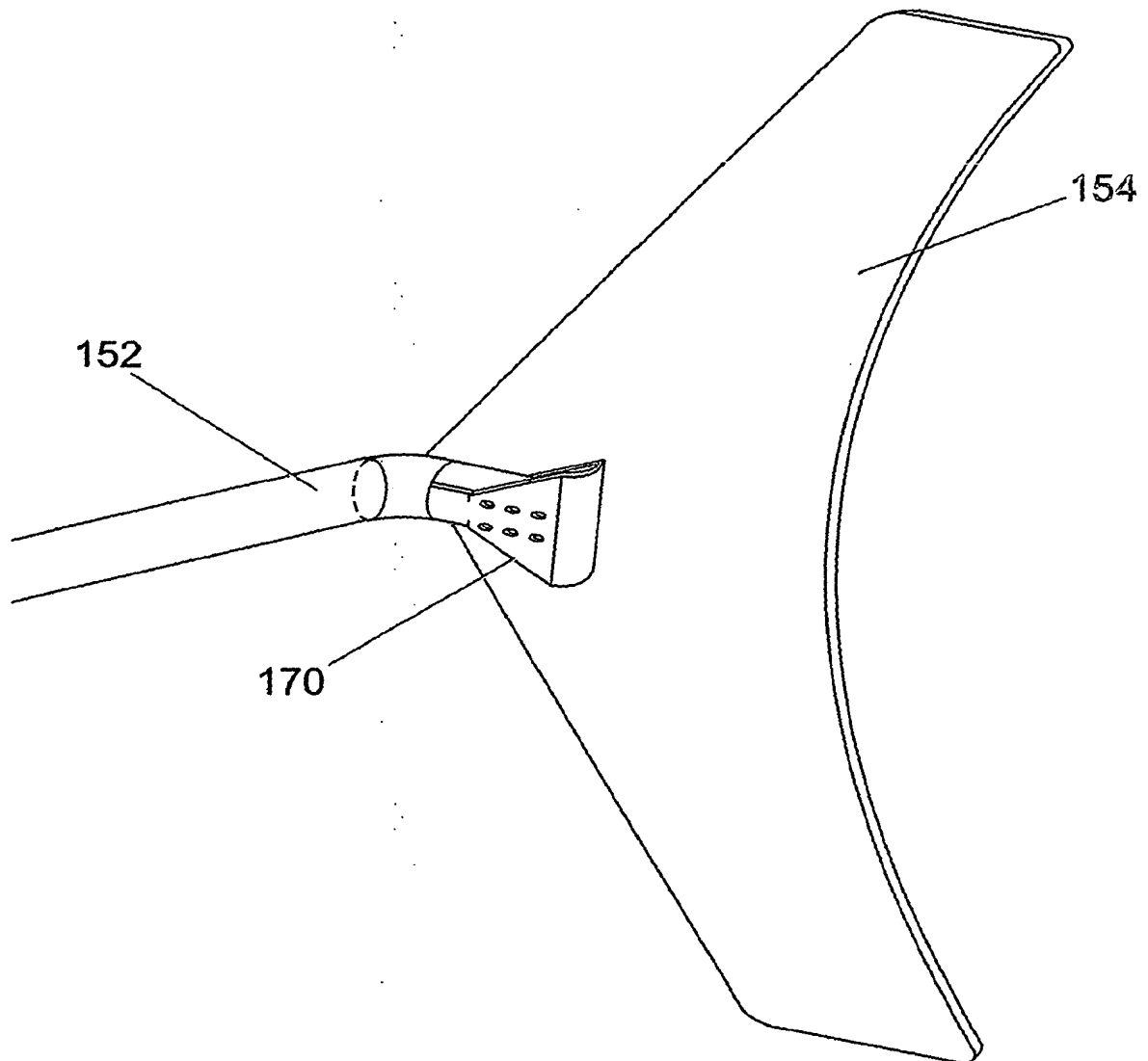


Fig. 4

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*Fig. 5a*

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*Fig. 5b*

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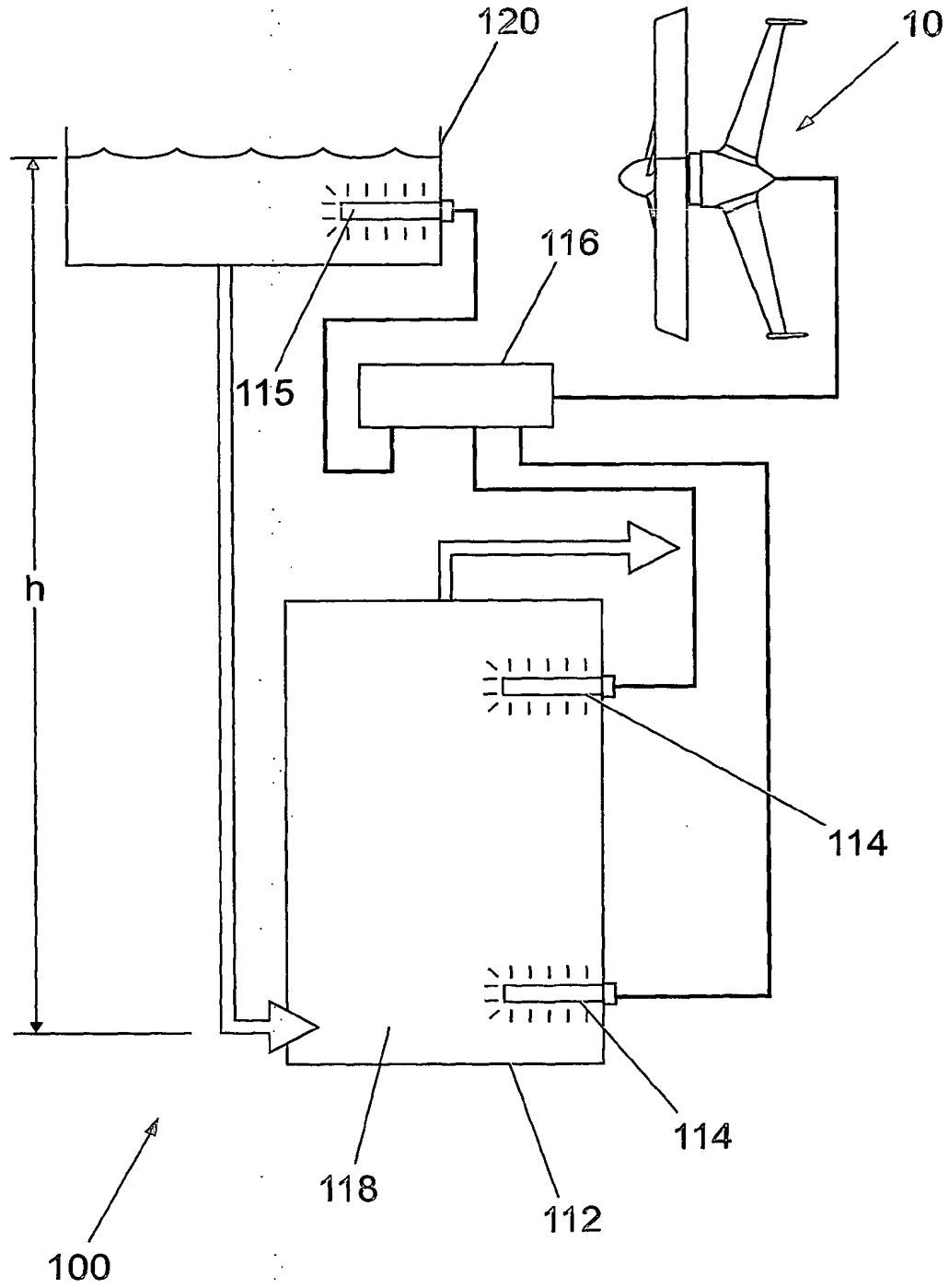


Fig. 6

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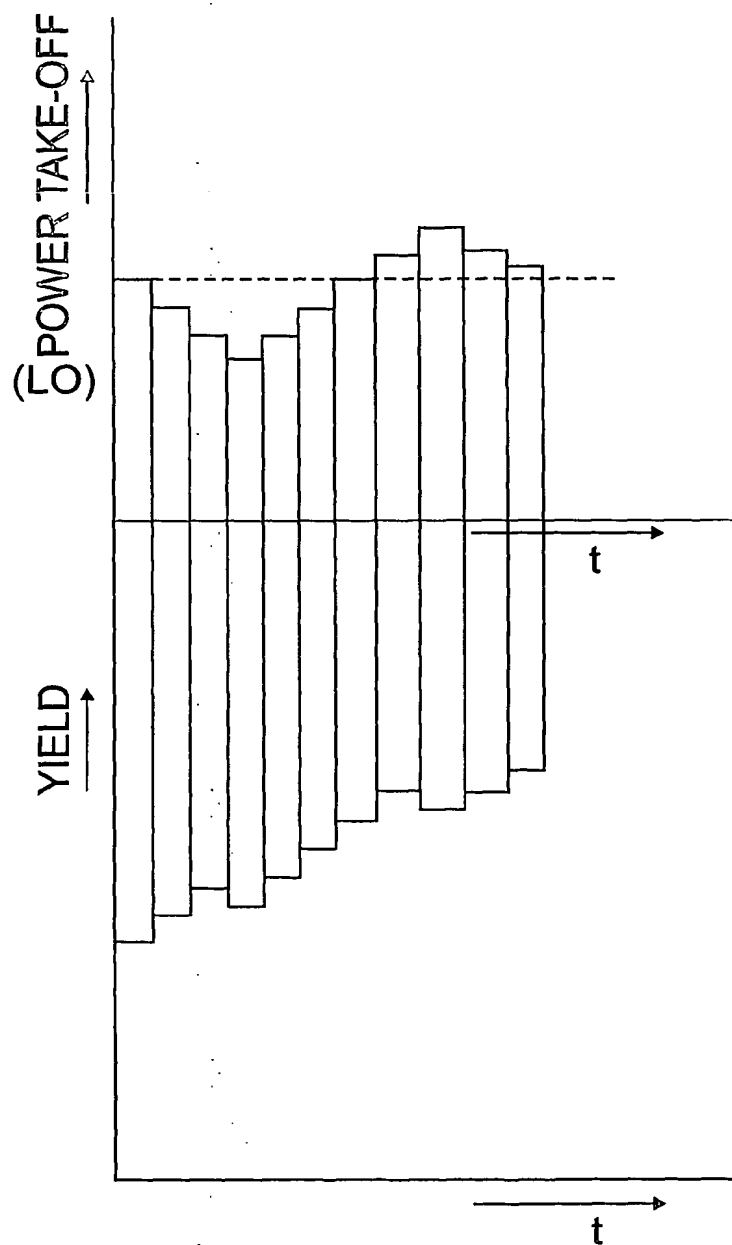
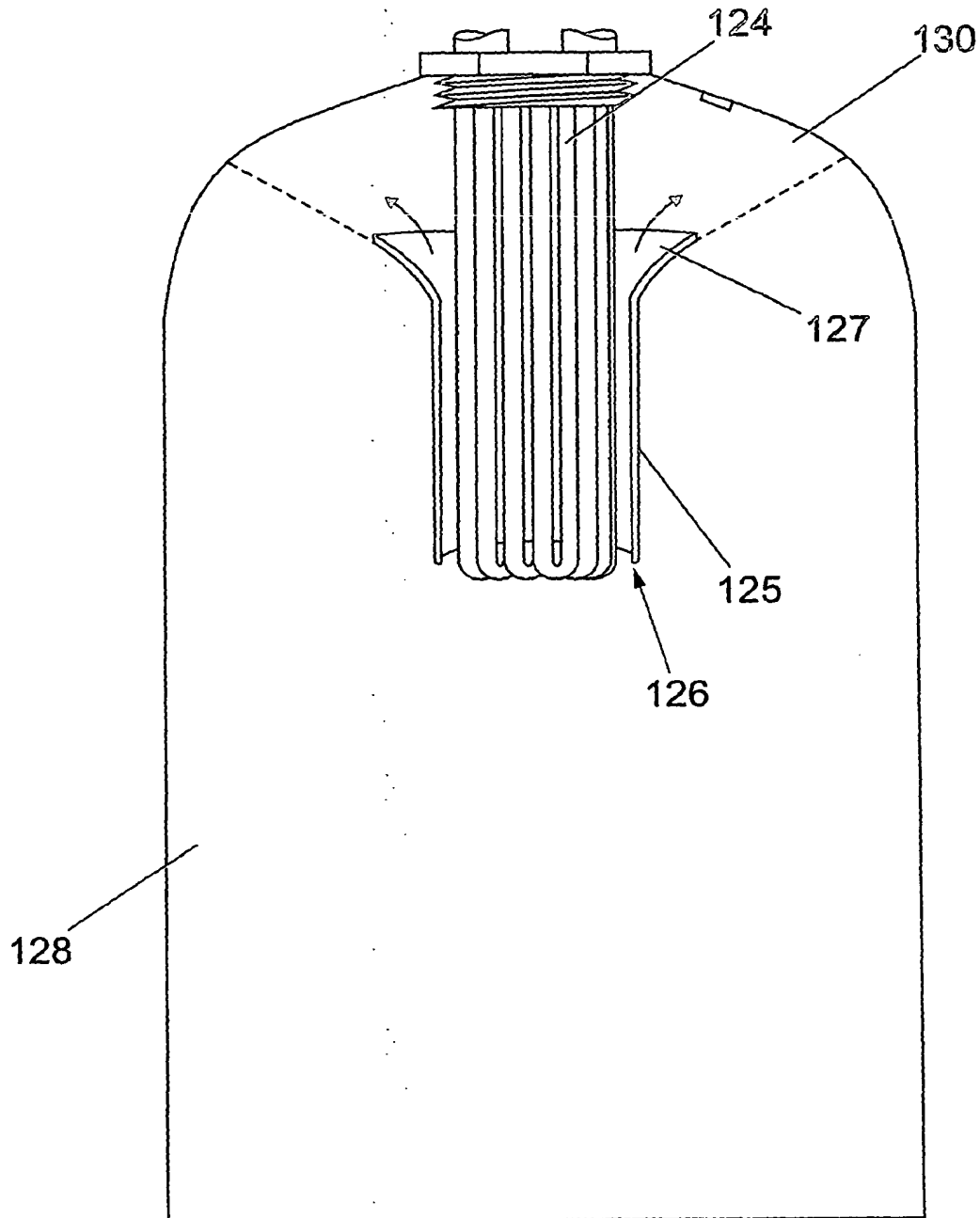


Fig. 7

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*Fig. 8a*

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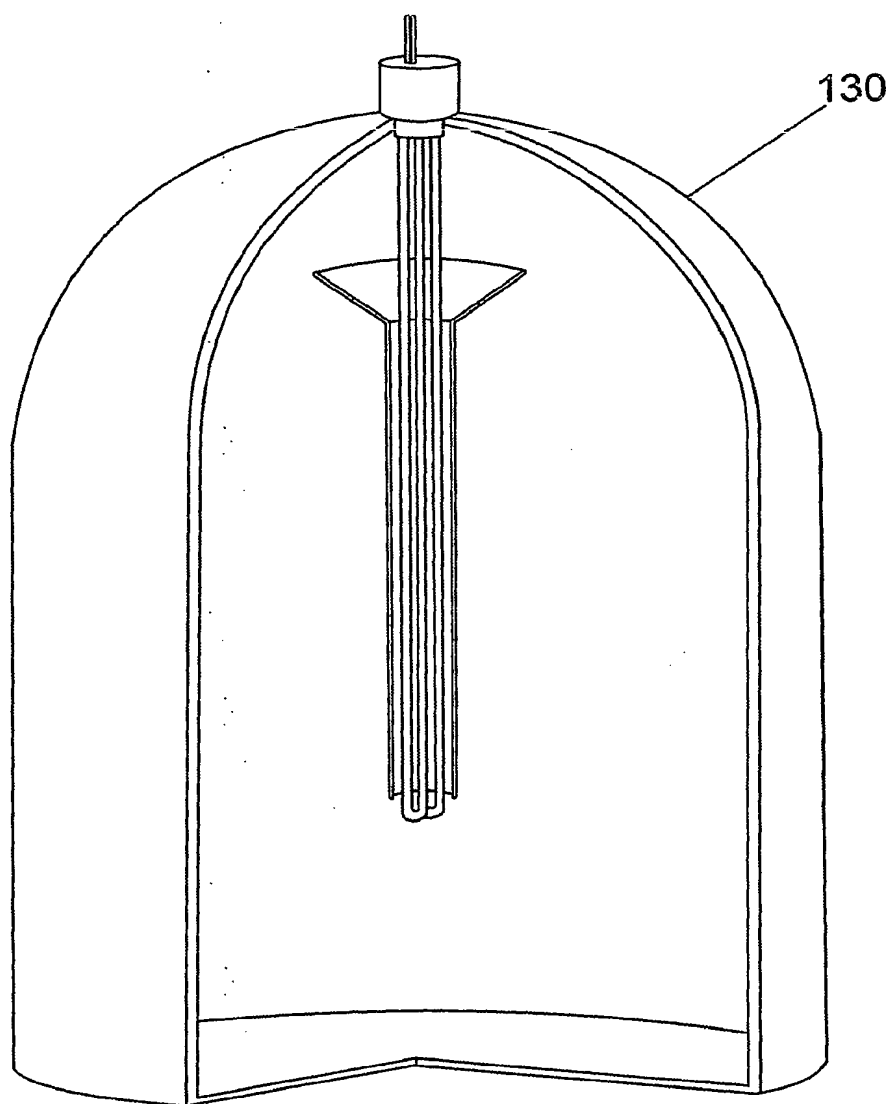
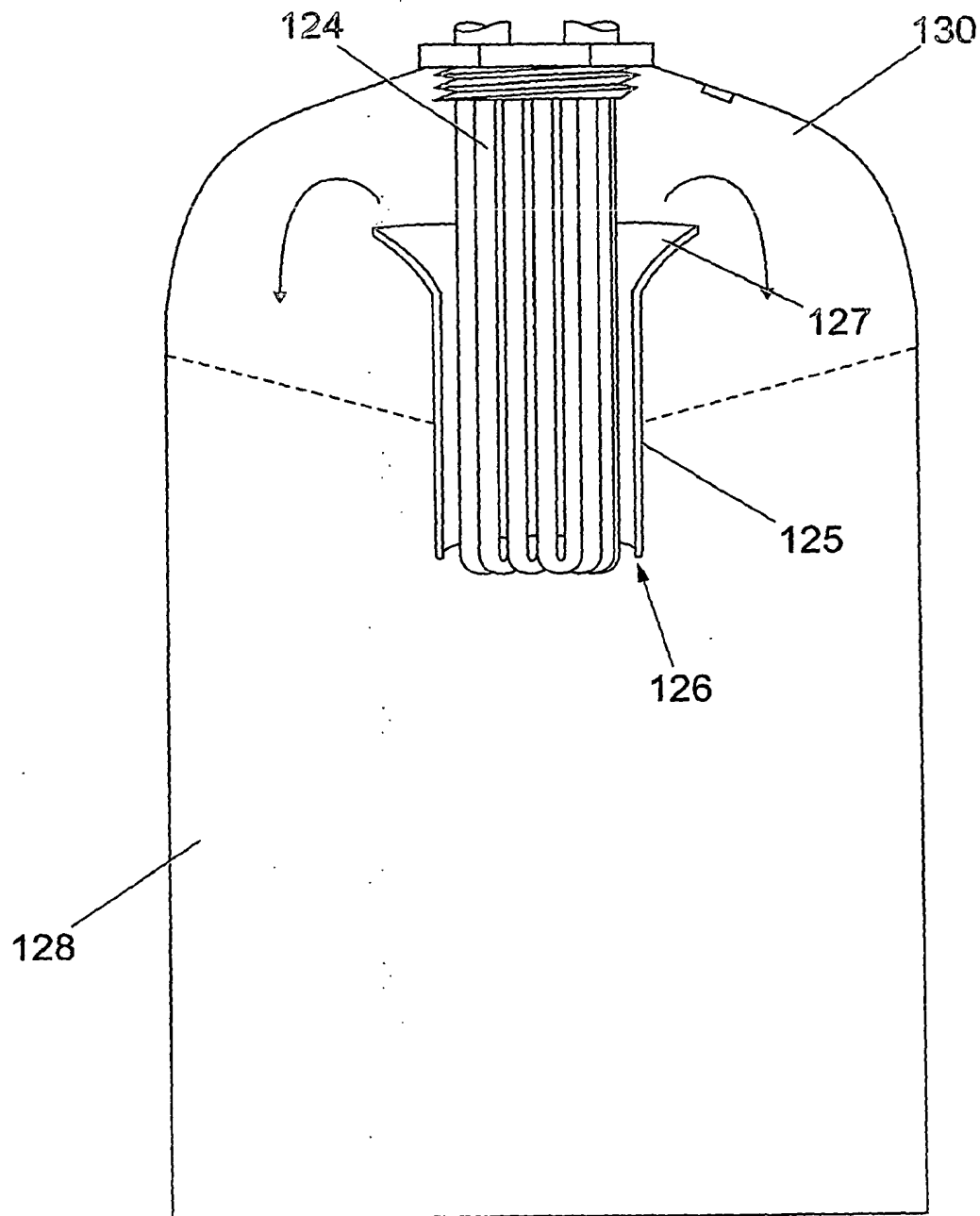


Fig. 8b

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*Fig. 9a*

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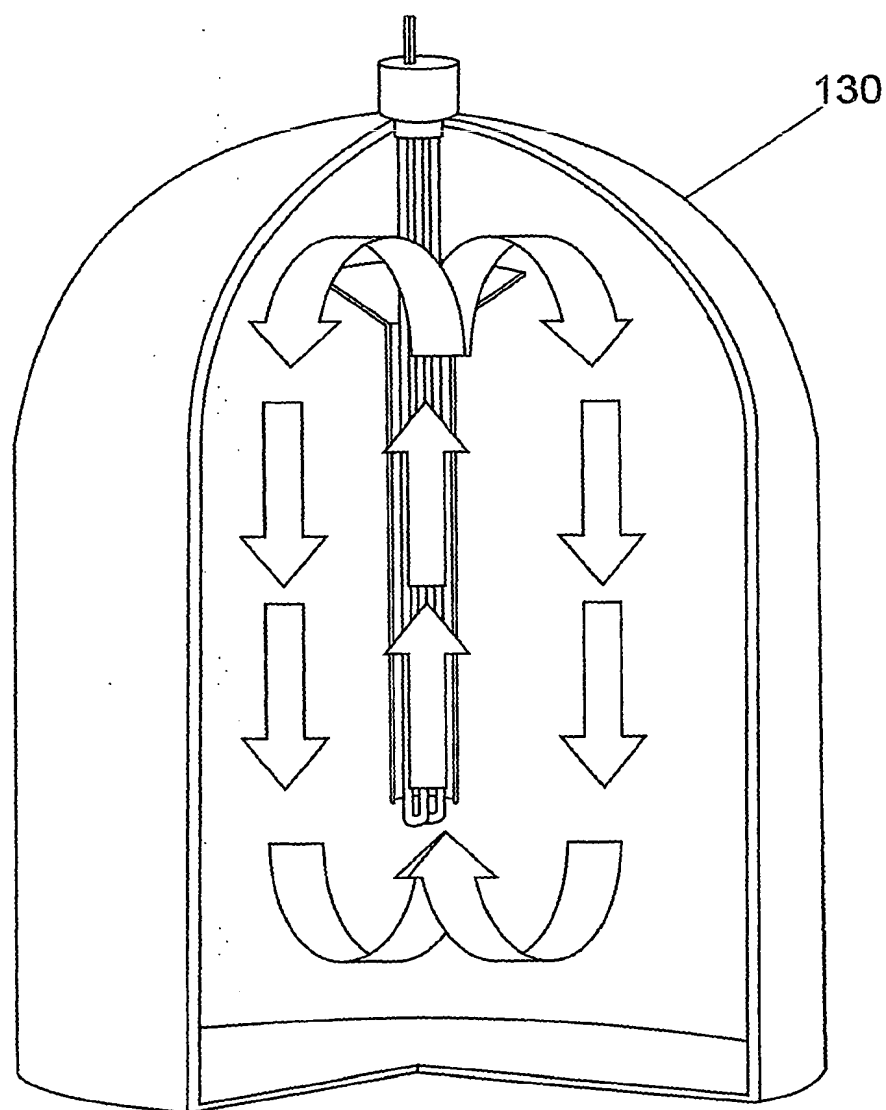


Fig. 9b

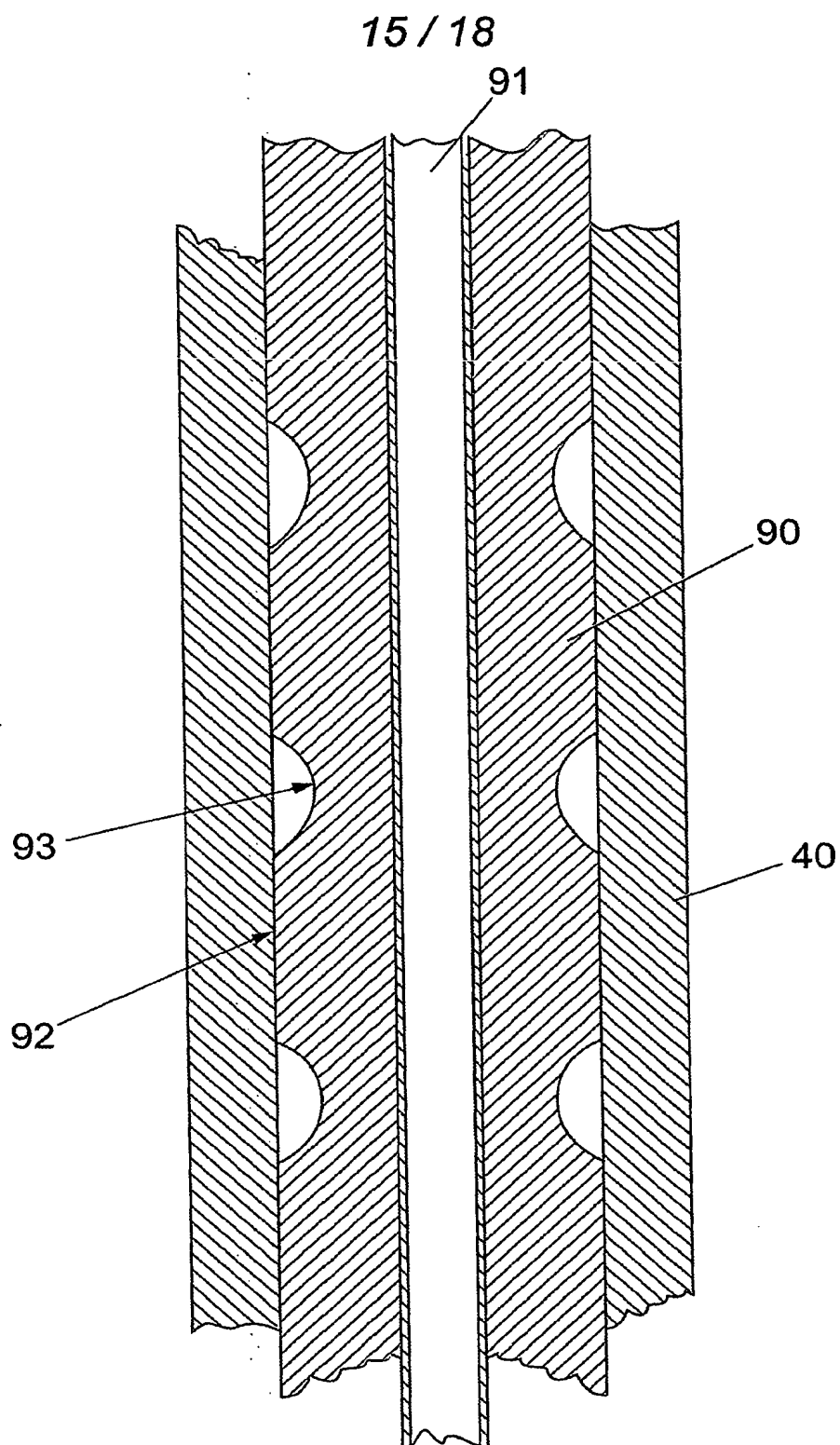


Fig. 10

SUBSTITUTE SHEET (RULE 26)

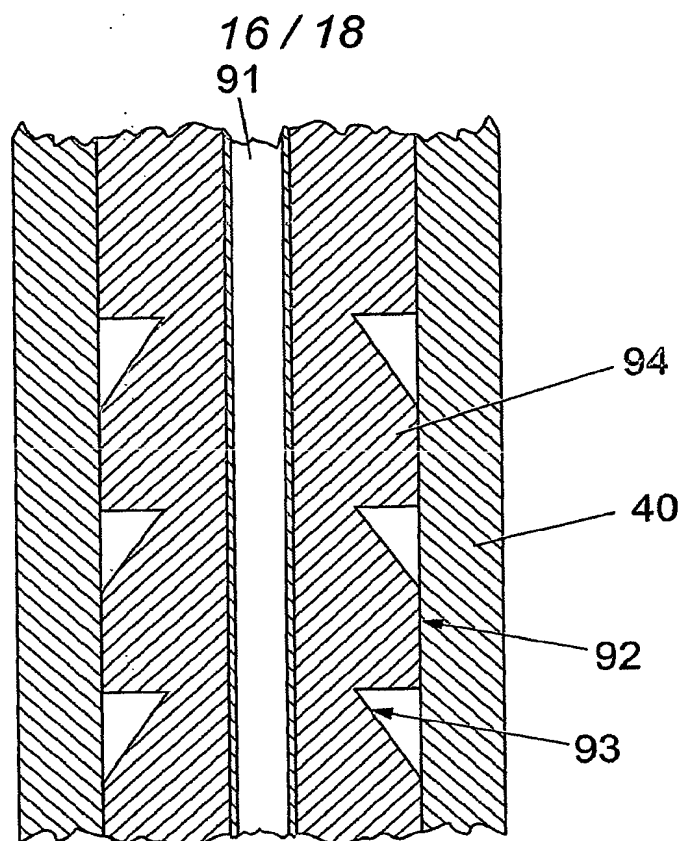


Fig. 11

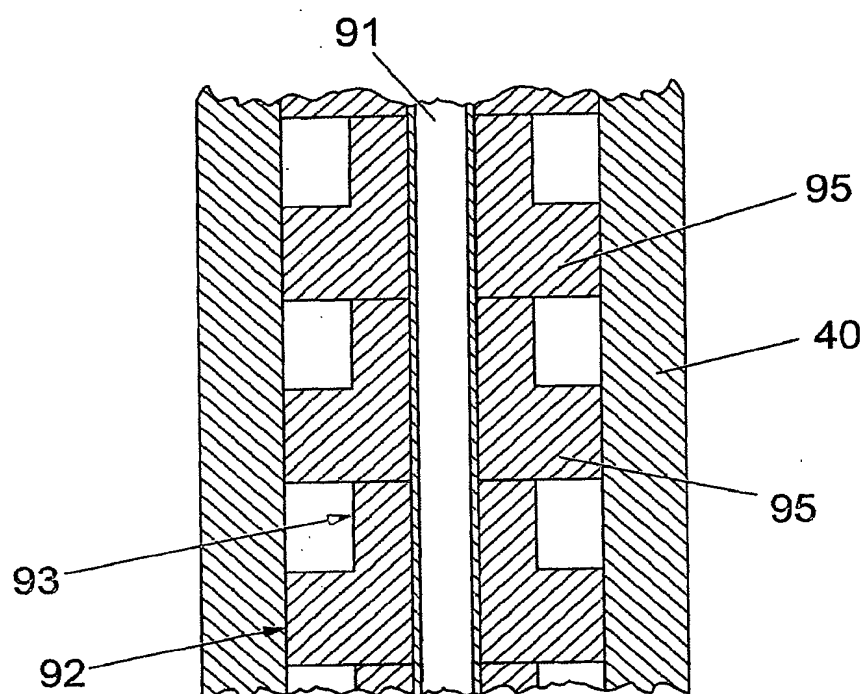
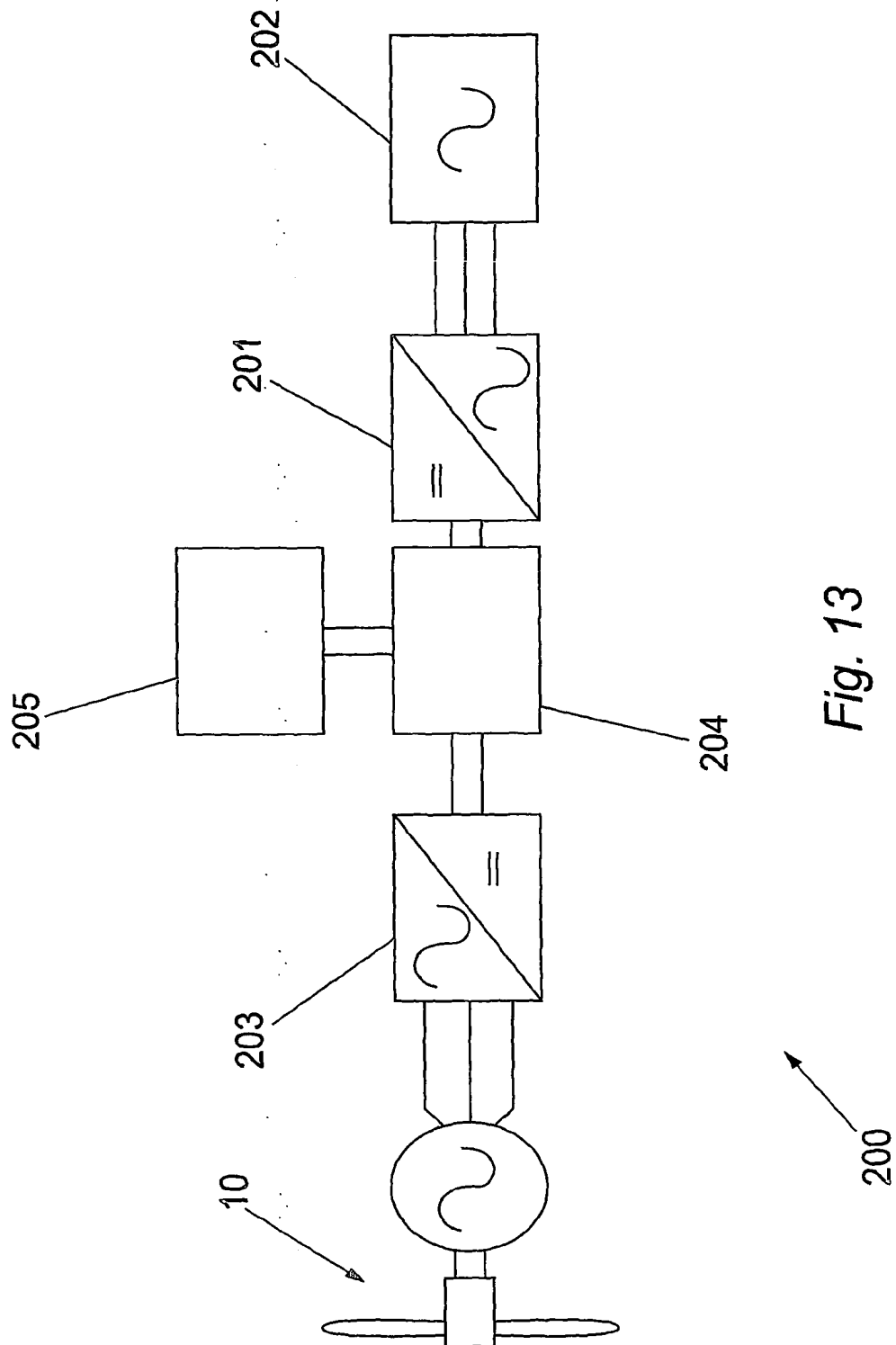


Fig. 12



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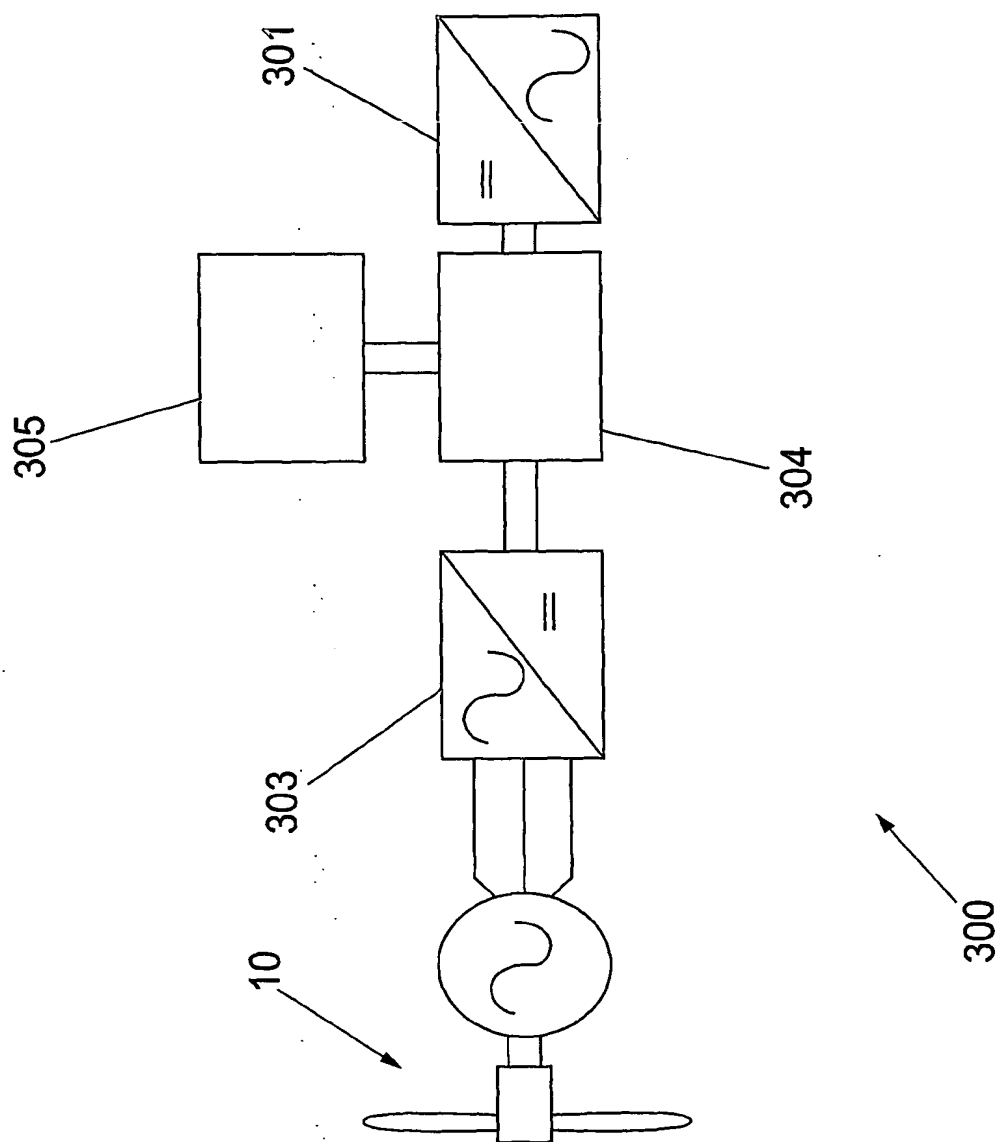


Fig. 14